HUMAN PHYSIOLOGY.

BY

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"Vastissimi studii primas quasi lineas circumscripsi."—HALLER.

WITH

FIVE HUNDRED AND THIRTY-TWO ILLUSTRATIONS

EIGHTH EDITION,

REVISED, MODIFIED, AND ENLARGED.

IN TWO VOLUMES.

VOL. I.

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Dedication to the First and Second Editions.

TO

JAMES MADISON,

EX-PRESIDENT OF THE UNITED STATES, ETC., ETC.,

ALIKE DISTINGUISHED AS AN ILLUSTRIOUS BENEFACTOR OF HIS COUNTRY,

A ZEALOUS PROMOTER OF SCIENCE AND LITERATURE,

AND THE FRIEND OF MANKIND,

This Work,

INTENDED TO ILLUSTRATE THE FUNCTIONS EXECUTED BY THAT BEING,

WHOSE MORAL AND POLITICAL CONDITION HAS BEEN WITH HIM AN OBJECT OF

ARDENT AND SUCCESSFUL STUDY,

IS, WITH HIS PERMISSION, INSCRIBED,

IN TESTIMONY OF UNFEIGNED RESPECT FOR HIS TALENTS AND PHILANTHROPY,

AND OF GRATITUDE FOR NUMEROUS EVIDENCES OF FRIENDSHIP,

BY HIS OBEDIENT AND OBLIGED SERVANT,

THE AUTHOR.

PREFACE TO THE EIGHTH EDITION.

The demand for another edition of this work has given occasion to a thorough revision of it by the author.

There is no department, perhaps, of medicine, to which the attention of so many investigators has been, and is, directed as to that of physiology; and, as remarked in the preface to the last edition, perhaps at no time in the history of the science have observers been more energetic, and discriminating. Many modifications of fact and inference have consequently taken place, which it has been necessary for the author to record, and to express his views in relation thereto. Especially has he endeavoured to note the phenomena that have presented themselves to the most accurate observers, and to deduce from them laws which may tend to enlarge the boundaries of the science: he has not, however, felt himself at liberty to discard the results of the observations of all former anthropologists, or the opinions they had embraced in regard to the various functions. It not unfrequently, indeed, happens, that in ignorance of the history of the science, views are esteemed new, which had been promulged by earlier investigators. He has, therefore, in an encyclopædiac work like the present, retained many of those opinions, whilst he has laboured to do especial justice to such as have emanated from more recent inquirers. In this respect, his work differs from valuable physiological treatises that are before the public. Whilst, too, he has inserted the main results of the labours of recent histologists, especially such as are directly applicable to physiology, he has not considered it advisable to pursue the subject to such an extent as if the work were on general anatomy, to which histology properly belongs.

On the whole subject of physiology proper, as it applies to the functions executed by the different organs, the present edition, the author flatters himself, will be found to contain the views of the most distinguished physiologists of all periods. The contributions to the science of life have, of late years, been rich and varied; and to collate and weigh them, and to separate the most trustworthy and valued, has been a work of no little discriminating labour,—but to the author a labour of love, inasmuch as they are subjects which he has been long accustomed to investigate; and on which he has annually to treat before the class of Institutes of Medicine in the Jefferson Medical College.

The rich collection of materials in the possession of his publishers has enabled him to increase greatly the list of illustrations, and to substitute in many cases better; whilst new cuts have been added, so as to make the whole number five hundred and thirty-two, in place of four hundred and seventy-four, as in the last edition. It has been difficult in all cases to assign these to the original projectors; but an effort has been made so to do.

The author need scarcely add, that no pains have been spared by him to make the work a complete expression of the science of the day. The list of *ex professo* publications[1] will indicate most of the numerous

[1] Atlee, Walter F., M. D. Notes of M. Bernard's Lectures on the Blood; with an appendix, Philad., 1854.

Bain, Alexander, A. M. The Senses and the Intellect, London, 1855.

Beale, Lionel John. The Laws of Health in relation to Mind and Body: A series of Letters from an old Practitioner to a Patient, Amer. edit., Philad., 1851.

Béclard, J. Traité Élémentaire de Physiologie Humaine comprenant les Principales Notions de la Physiologie Comparée, Ouvrage accompagné de 144 Gravures intercalées dans le Texte, Paris, 1855.

Becquerel, M. Alf. and Rodier, M. A. Traité de Chimie Pathologique appliquée à la Médecine Pratique, Paris, 1854.

Bérard, P. Cours de Physiologie, fait a la Faculté de Médecine de Paris. Tome 3ème et 2 livraisons du Tome 4ème, 1851–1855.

Béraud, M. J. B. Manuel de Physiologie de l'Homme et des Principaux Vertébrés; répondant à toutes les Questions Physiologiques du Programme des Examens de Fin d'Année, revu par M. Ch. Robin, &c., Paris, 1853.

Bernard, M. Claude. Leçons de Physiologie Expérimentale appliquée à la Médecine, faites au Collége de France, avec 22 figures intercalées dans le Texte, Paris, 1855.

———, see Atlee.

Bidder, Dr. F., and Schmidt, Dr. C. Die Verdauungssäfte und der Stoffwechsel. Eine Physiologisch-Chemische Untersuchung. Mit fünf Tafeln graphischer Darstellungen, Mitau und Leipzig, 1852.

Bishop, John, F. R. S. On Articulate Sounds; and on the Causes and Cure of Impediments of Speech, London, 1851.

distinct treatises, connected with biology, which he has had to consult in the preparation of the present edition. He has, moreover, industriously

Bock, Dr. Carl Ernst. Lehrbuch der Pathologischen Anatomie und Diagnostik, 2 Bd., Leipzig, 1852–1853.

Bowman, John E., F. C. S. A Practical Handbook of Medical Chemistry; 2d American from the third and revised London edition, with illustrations, Philad., 1855.

Brachet, J. L. Physiologie Élémentaire de l'Homme, 2de édit., 2 vols., Paris et Lyon, 1855.

Brodie, Sir Benjamin, Bart., D. C. L., &c. Physiological Researches, London, 1851.

Brown-Séquard, Experimental Researches applied to Physiology and Pathology, New York, 1853.

———, Sur les Resultats de la Section et de la Galvanisation du Nerf Grand Sympathique au Cou. (Extrait de la Gazette Médicale de Paris, Année, 1854.)

———, Experimental and Clinical Researches on the Physiology and Pathology of the Spinal Cord, and some other parts of the Nervous Centres, Richmond, 1855.

———, Recherches Expérimentales sur la Transmission Croisée des Impressions Sensitives dans la Moëlle Épinière. (Extrait de la Gazette Hebdomadaire de Médecine et de Chirurgie. Tome ii., Nos. 31 and 36), Paris, 1855.

———, Propriétés et Fonctions de la Moëlle Épinière, Rapport sur quelques Expériences de M. Brown-Séquard, lu à la Société de Biologie, le 21 Juillet, 1855, par M. Paul Broca, Professeur Agrégé, &c., Paris, 1855.

———, Deux Mémoires sur la Physiologie de la Moëlle Épinière lus à l'Académie des Sciences le 27 Août et le 24 Septembre, 1855.

1. Recherches sur la Voie de Transmission des Impressions Sensitives dans la Moëlle Épinière.
2. Recherches Expérimentales sur la Distribution des Fibres des Racines Postérieures dans la Moëlle Épinière, et sur la Voie de Transmission des Impressions Sensitives dans cet Organe. (Extraits de la Gazette Médicale de Paris, Année, 1855).

[The last four memoirs—the gift of Dr. Brown-Séquard—reached the author whilst he was preparing the present list. The results at which he has arrived from his experiments on living animals, and published in the two memoirs presented before the Académie des Sciences, of Paris, conflict greatly with those hitherto received by physiologists, in regard to the functions of the vesicular and tubular portions of the spinal marrow. In the first of the two memoirs he concludes,—that it is not by the posterior cords of the spinal marrow, as is generally admitted in France, that the transmission to the encephalon of sensory impressions, received by the trunk and the limbs, is finally effected; that such transmission is finally effected by the gray substance of the medulla spinalis, and especially by its central portion;—and in the latter memoir he concludes, that sensory impressions on their arrival at the medulla spinalis, pass by the posterior cords, the posterior gray cornua, and probably also by the lateral cords; and that in these different portions of the medulla they ascend or descend; and after a short course towards the encephalon, or in the opposite direction, quit those parts to enter into the gray central matter, in which, or by which, they are finally transmitted to the encephalon.

The brilliant vivisections made by this dexterous experimenter and able physiologist, in the presence of a Committee of the Société de Biologie, composed of MM. Claude Bernard, Bouley, Broca, Giraldès, Goubaux and Vulpian, have led M. Broca—the reporter—to the sweeping conclusion, that "no known doctrine or system can live alongside the experiments of M. Brown-Séquard; and that we must submit to make a *tabula rasa* of everything that has been hitherto said on the physiology of the medulla spinalis."

availed himself of multitudinous contributions to medical encyclopædias, dictionaries, and journals, published at home and abroad; and, for the

The Committee considered, that the experiments, performed in their presence, satisfactorily demonstrated—that exposure of the dura mater and of the medulla permitted sensibility and motion to persist in the posterior *train*;—that such sensibility still persisted after the section of the posterior cords—called the sensitive cords of the medulla; and that, consequently, these cords are not indispensable for the transmission of sensory impressions;—that far from abolishing sensibility, the section of the supposed sensitive cords was accompanied by hyperæsthesia of the lower limbs; that after such section, the caudal segment of the medulla was more sensible than the cephalic segment, and that the vesicular matter of the cord was of itself insensible.

Other experiments showed, that the separate and complete section of the posterior cords neither destroyed sensibility nor motion; but that both were destroyed when the vesicular matter was cut across; that the integrity of the antero-lateral cords did not prevent the loss of movement, nor did that of the posterior cords prevent the loss of feeling.

A work on the physiology of the spinal marrow, from the pen of Dr. Brown-Séquard, is announced. It will, doubtless, contain all the facts observed by him, as well as the important deductions to which his ample knowledge of the whole subject cannot fail to have led him.]

Budd, Geo., M. D., F. R. S. On Diseases of the Liver, 2d Amer. from the last and improved London edition, with colored plates and wood-cuts, Philad., 1853.

————, On the Organic Diseases and Functional Disorders of the Stomach, Amer. edit., Philad., 1856.

Budge, Julius. Memoranda der Speciellen Physiologie des Menschen; ein Leitfaden für Vorlesungen und zum Selbststudium, 5te verbesserte und vermehrte Auflage. Mit 10 Kupfertafeln, Weimar, 1853.

Bushnan, J. Stevenson, M. D. The Principles of Animal and Vegetable Physiology; a Popular Treatise on the Functions and Phenomena of Organic Life; to which is prefixed a general view of the great Departments of Human Knowledge, with one hundred and two Illustrations on wood. [Reprinted from vol. 1 of Orr's Circle of the Sciences, London, 1854.] Philadelphia, 1854.

Carpenter, William B., M. D., F. R. S., &c. Principles of Human Physiology, with their Chief Applications to Psychology, Pathology, Therapeutics, Hygiène, and Forensic Medicine. A new American from the last London edition, with two hundred and sixty-one Illustrations. Edited, with additions, by Francis Gurney Smith, M. D., Professor of the Institutes of Medicine in the Medical Department of Pennsylvania College, &c., Philad., 1855.

————, Principles of Comparative Physiology, with three hundred and nine wood engravings. A new American from the fourth and revised London edition, Philad., 1854.

Chambers, Thomas K. Digestion and its Derangements. The Principles of Rational Medicine applied to Disorders of the Alimentary Canal, London, 1856.

Coste, M. Histoire Générale et Particulière du Développement des Corps Organisés, Publié sous les Auspices de M. Villemain, Ministre de l'Instruction Publique, Paris, 1847–1854.

Eschricht, Dr. Daniel Friedrich. Das Physische Leben in Populären Vorträgen. Mit 208 Abbildungen, meist in Holz geschnitten, Kopenhagen, 1852.

Fabius and Buys-Ballot. De Spirometro ejusque Usu. Dissertatio Inauguralis, Amstelodam., 1853.

eighth time, he ventures to place the work before a profession, which, he is proud in being permitted again to state, has already done too

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———, De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2ème Édition, Paris, 1855.

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———, See Günther.

———, See Wagner.

Gavarret, J. Physique Médicale. De la Chaleur produite par les Etres Vivants, Avec 41 figures dans le Texte, Paris, 1855.

Gluge, Dr. Gottlieb. Pathologische Histologie. Mit 12 Kupfertafeln und Tabellen, Jena, 1850; Translated, under the Title, Atlas of Pathological Histology, by Dr. Gottlieb Gluge, &c., &c., from the German, by Joseph Leidy, M. D., &c. &c., Philad., 1853.

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Holland, (Sir) Henry, M. D., F. R. S. Chapters on Mental Physiology, London, 1852.

Jochman, Dr. Paul Alex., Beobachtungen über die Körperwärme in chronischen fieberhaften Krankheiten. Mit zwei lithographirten Tafeln, Berlin, 1853.

Jones, C. Handfield, M. B. F. R. S., and Edward H. Sieveking, M. D. A Manual of Pathological Anatomy. First American edition, revised, with three hundred and ninety-seven Illustrations, Philad., 1854.

Keber, G. A. F. De Spermatozoorum Introitu in Ovula, Königsberg, 1853.

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Kitto, John, D. D., F. S. A. The Lost Senses. Series 1. Deafness, London, 1853. Series 2. Blindness, London, 1845.

Kobelt, Dr, De l'Appareil du Sens Génital des deux Sexes dans l'Espèce Humaine et dans quelques Mammifères, au point de Vue Anatomique et Physiologique. Traduit de l'Allemand par H. Kaula, D. M. Avec cinq Planches lithographiées, Strasbourg et Paris, 1851.

Kölliker, Dr. A. Mikroskopische Anatomie oder Gewebelehre des Menschen, 2ter Band., Leipzig, 1850–1854.

———, Manual of Human Histology, translated and edited by George Busk, F. R. S., and Thomas Huxley, F. R. S. Sydenham Society's edition, 2 vols., London, 1853–1854. American edition under the title, Manual of Human Microscopical Anatomy, edited with notes and additions by J. Da Costa, M. D., illustrated by three hundred and thirteen Engravings on wood, Philad., 1854.

Lehmann, Prof. C. G. Lehrbuch der Physiologischen Chemie, 2te gänzlich neu umgearbeite Auflage, 3 Bd. Leipz., 1850–1852. Translated for the Cavendish Society, by Dr. Geo. E. Day, M. D., F. R. S. Amer. edition by Prof. R. E. Rogers, M. D., with Illustrations selected from Funke's Atlas of Physiological Chemistry, and an Appendix of Plates, 2 vols, Philad., 1855.

———, Handbuch der Physiologischen Chemie, Leipzig, 1854, translated under

much honor to his efforts to be useful. His crowning desire, in all his literary undertakings connected with his profession, has been to

the following Title, Manual of Chemical Physiology, from the German of Prof. C. G. Lehmann, M. D., translated with notes and additions by J. Cheston Morris, M.D., with an Introductory Essay on Vital Force, by Samuel Jackson, M. D., Professor of Institutes of Medicine in the University of Pennsylvania, and illustrated with forty Woodcuts, Philad., 1856.

Liebig, Justus Von. Familiar Letters on Chemistry, in its relations to Physiology, Dietetics, Agriculture, Commerce, and Political Economy, 3d edition, revised and much enlarged, London, 1851.

Longet, F. A. Traité de Physiologie, Ouvrage accompagné de figures dans le texte et de planches en taille-douce, Tom. 1èr, Fascicul. 3, Paris, 1852.

Ludwig, C. Lehrbuch der Physiologie des Menschen, 1ste Band, Heidelberg, 1852–1853; und 2ter Band, 1ste Abtheilung, Leipzig und Heidelberg, 1855, 2te Abth. 1856.

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Moser, Dr. A., and Dr. J. C. Strahl. Handbuch der Physiologischen und Pathologischen Chemie, nach den neusten Quellen bearbeitet, Leipzig, 1851.

Noble, Daniel, M. D., Elements of Psychological Medicine: An Introduction to the Practical Study of Insanity, adapted for Students and Junior Practitioners, London, 1853.

Oesterlen, Dr. Fr. Handbuch der Hygieine für den Einzelnen wie für eine Bevölkerung, Tubingen, 1851.

Paget, James, F. R. S. Lectures on Surgical Pathology, delivered at the Royal College of Surgeons of England; Hypertrophy, Atrophy, Repair, Inflammation, Mortification, Specific Diseases, and Tumors, Amer. edit., Philad., 1854.

Prochaska. See Unzer and Prochaska.

Robin, Charles. See Atlee, Walter F.

———————, et F. Verdeil. Traité de Chimie Anatomique et Physiologique Normale et Pathologique ou des Principes Immédiats Normaux et Morbides qui constituent le Corps de l'Homme et des Mammifères, accompagné d'un Atlas de 45 Planches gravées, en partie coloriées, 3 vols., Paris, 1853.

Segond, L. A. Traité d'Anatomie Générale: Théorie de la Structure, embrassant les Substances Organiques et les Éléments, les Tissus, les Membranes et les Parenchymes, Paris, 1854.

Sieveking, Edward H. See Jones, C. Handfield.

Strahl, Dr. J. C. See Moser, Dr. A.

Tardieu, Ambroise. Dictionnaire d'Hygiène Publique et de Salubrité ou Répertoire de toutes les Questions rélatives a la Santé Publique, considérées dans leurs Rapports avec les Substances, les Épidémies, les Professions, les Établissements et Institutions d'Hygiène et de Salubrité, complété par le Texte des Lois, Décrets, Arrêtés, Ordonnances et Instructions qui s'y rattachent, 3 vols., Paris, 1852–1854.

Thomas, Dr. E. Die Physiologie des Menschen, Leipzig, 1853.

Todd, Robert Bentley, M. D., F. R. S., and Bowman, Wm., F. R. S. The Physiological Anatomy and Physiology of Man, Pt. iv., Sect. 1, London, 1852, Amer. edit., Philad., 1853.

Unzer and Prochaska. The Principles of Physiology, by John Augustus Unzer, and A Dissertation on the Functions of the Nervous System, by George Prochaska, translated and edited by Thomas Laycock, M. D. (Sydenham Society's edit.), London, 1851.

facilitate the onward course of those, who are pressing forward for distinction in a truly learned and difficult avocation; and the reception, which his undertakings have met with, has abundantly satisfied him that his labours have been far from fruitless.

ROBLEY DUNGLISON.

18 Girard St.
May, 1856.

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Wedl, Carl, M. D. Rudiments of Pathological Histology, with 172 Illustrations on wood, translated from the German, and edited by George Busk, F. R. S. (Sydenham Society's edition), London, 1855.

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HUMAN

PHYSIOLOGY.

PROLEGOMENA.

I. NATURAL BODIES.

THE extensive domain of Nature is divisible into three great classes: —*Minerals*, *Vegetables*, and *Animals*. This division was universally adopted by the ancients, and still prevails, especially amongst the unscientific. When, however, we carefully examine their respective characteristics, we discover, that the animal and the vegetable resemble each other in many essential particulars. This resemblance has given occasion to the partition of all bodies into two classes: the *Inorganic*, or those not possessing *organs* or instruments adapted for the performance of special actions or functions, and the *Organized*, or such as possess this arrangement.

In all ages, philosophers have attempted to point out a

> "Vast chain of being, which from GOD began,
> Nature's ethereal, human, angel, man,
> Beast, bird, fish, insect, what no eye can see,
> No glass can reach—"

the links of which chain they have considered to be constituted of all natural bodies; passing by insensible gradations through the inorganic and the organized, and forming a rigid and unbroken series; and in which, they have conceived,

> "——— Each moss,
> Each shell, each crawling insect, holds a rank,
> Important in the plan of Him who framed
> This scale of beings—holds a rank which, lost,
> Would break the chain, and leave behind a gap
> Which Nature's self would rue."

Crystallization has been esteemed by them as the highest link of the inorganic kingdom; the lichen, which encrusts the stone, as but one link higher than the stone itself; the mushroom and the coral as the connecting links between the vegetable and the animal; and the immense space, which separates man—the highest of the mammalia—from his Maker, they have conceived to be occupied in succession by beings of gradually increasing intelligence. If, however, we investigate the matter minutely, we discover that many links of the chain appear widely separated from each other; and that, in the existing state of our knowledge, the catenation cannot be esteemed rigidly maintained.[1] Let us inquire into the great characteristics of the different kingdoms, and endeavour to describe the chief points in which living bodies differ from those that have never possessed vitality, and into the distinctions between organized bodies themselves.

1. DIFFERENCE BETWEEN INORGANIC AND ORGANIZED BODIES.

Inorganic bodies possess the common properties of matter. Their elements are fixed under ordinary circumstances. Their study constitutes *Physics*, in its enlarged sense, or *Natural Science*. Organized bodies have properties in common with inorganic, but they have likewise others superadded, which control the first in a singular manner. They are beings, whose elements are undergoing constant mutation, and the sciences treating of their structure and functions are *Anatomy* and *Physiology*.

They differ from each other in—

1. *Origin.*—Inorganic bodies are not born: they do not arise from a parent: they spring from the general forces of matter,—the particles being merely in a state of aggregation, and their motions regulated by certain fixed and invariable laws. The animal and the vegetable, on the other hand, are products of generation; they must spring from beings similar to themselves: and they possess the *force of life*, which controls the ordinary forces of matter. Yet it has been supposed, that they are capable of creating life; in other words, that a particular organization presupposes life. This is not the place for entering into the question of generation. It will be sufficient at present to remark, that in the upper classes of animals, the necessity of a parent cannot be contested; the only difficulty that can possibly arise regards the very lowest classes; and analogy warrants the conclusion, that every living being must spring from an egg or a seed.

2. *Shape.*—The shape of inorganic bodies is not fixed in a determinate manner. It is true, that by proper management every mineral can be reduced to a primitive nucleus, which is the same in all minerals of like composition; still, the shape of the mineral, as it presents itself to us, differs. Carbonate of lime, for example, although it may always be reduced to the same primitive nucleus, assumes various appearances;—being sometimes rhomboidal; at others, in regular hexahedral prisms;—in solids, terminated by twelve scalene triangles, or in dodecahedrons, whose surfaces are pentagons. In organized bodies, on the contrary, the shape is constant. Each animal and vegetable has the one that characterizes its species, so that no possible mistake can be indulged; and this applies not only to the whole body, but to every one of its parts, numerous as they are.

3. *Size.*—The size of an inorganic body is by no means fixed. It may be great, or small, according to the quantity present of the particles that have to form it. A crystal, for example, may be minute, or the contrary, according to the number of saline particles in the solution. On the other hand, organized bodies attain a certain size,—at times by a slow, at others by a more rapid growth,—but in all cases

[1] Fleming's Philosophy of Zoology, i. 4. Edinburgh, 1822.

the due proportion is preserved between the various parts,—between the stem and the root, the limb and the trunk. Each vegetable and each animal has its own size, by which it is known; and although we occasionally meet with dwarf or gigantic varieties, these are unfrequent, and mere exceptions establishing the position.

4. *Chemical character.*—Great difference exists between inorganic and organized bodies in this respect. In the mineral kingdom are found all the elementary substances, or those which chemistry, at present, considers *simple;* amounting to at least sixty-two. They are as follows:—*Non-metallic bodies.* Oxygen, hydrogen, nitrogen, sulphur, selenium, phosphorus, chlorine, iodine, bromine, fluorine, carbon, boron, silicon. *Metals.* Potassium, sodium, lithium, calcium, magnesium, barium, strontium, aluminium, glucinium, zirconium, yttrium, thorium, iron, manganese, zinc, cadmium, lead, tin, copper, bismuth, mercury, silver, gold, platinum, rhodium, palladium, osmium, iridium, nickel, cobalt, uranium, cerium, antimony, arsenic, chromium, molybdenum, tungsten, columbium, tellurium, titanium, vanadium, lantanium, didymium, erbium, terbium, niobium, ruthenium, norium, ilmenium, aridium (?), and donarium (?). In the organized, a few only of these elements of matter are met with, viz., oxygen, hydrogen, nitrogen, and carbon, which are always present; and sulphur, phosphorus, chlorine, iodine, bromine, fluorine, potassium, sodium, calcium, magnesium, silicon, aluminium, iron, manganese, titanium, and arsenic, which are usually in small proportion.

The composition of inorganic bodies is more simple: several consist of but one element; and, when composed of more, the combination is rarely higher than ternary. Organized bodies, on the other hand, are never simple, nor even binary. They are always at least ternary or quaternary. The simplest vegetable consists of a union of oxygen, carbon, and hydrogen; the simplest animal, of oxygen, hydrogen, carbon, and nitrogen.

The composition of the mineral, again, is constant. Its elements have entirely satisfied their affinities; and all remains at rest. In the organized kingdom, the affinities are not satisfied; compounds are formed to be again decomposed, and this happens from the earliest period of fœtal formation till the cessation of life; all is in commotion, and the chemical character of the corporeal fabric is incessantly undergoing modification. This applies to every organized body; and, accordingly, change of some kind is essential to our idea of active life. In the case of the seed, which has remained unaltered for centuries, and subsequently vegetates under favorable circumstances, life may be considered to be dormant or suspended. It possesses vitality, or the power of being excited to active life under favoring influences.

In chemical nomenclature, the term *element* has a different acceptation, according as it is applied to inorganic or organic chemistry. In the former, it means a substance, which, in the present state of science, does not admit of decomposition. We say, "in the present state of the science," for several bodies, now esteemed compound, were, not many years ago, classed amongst the simple or elementary. It is not much more than forty years since the alkalies were found to be composed of two elements. Previously, they were considered simple. In the animal and the vegetable, we find substances, also called *elements*, but with the epithet *organic* prefixed, because they are only found in *organized* bodies; and are therefore the exclusive products of organization and life. For example, in both animals and vegetables we meet with oxygen, hydrogen, carbon, nitrogen, and different metallic substances: these are *chemical* or *inorganic elements*. We further meet with albumen, gelatin, fibrin, casein, &c., substances which constitute the various organs, and have, therefore, been termed *organic elements* or *compounds of organization;* yet they are capable of decomposition; and in one sense, therefore, not elementary.

In the inorganic body, all the elements that constitute it are formed by the agency of general chemical affinities; but, in the organized, the formation is produced by the force that presides over the formation of the organic elements themselves—the force of life. Hence, the chemist is able to recompose many inorganic bodies; whilst the products of organization and life set his art at defiance.

The different parts of an inorganic body enjoy an existence independent of each other; whilst those of the organized are materially dependent. No part can, indeed, be injured without the mass and the separated portion being more or less affected. If we take a piece of marble, which is composed of carbonic acid and lime, and break it into a thousand fragments, each portion will be found to consist of carbonic acid and lime. The mass will be destroyed; but the pieces will not suffer from the disjunction. They will continue as fixed and unmodified as at first. Not so with an organized body. If we tear the branch from a tree, the stem itself participates more or less in the injury; the detached branch speedily undergoes striking changes; it withers; becomes shrivelled; and, in the case of the succulent vegetable, undergoes decomposition; certain of its constituents, no longer held in control by vital agency, enter into new combinations, are given off in the form of gas, and the remainder sinks to earth.

Changes, no less impressive, occur in the animal when a limb is separated from the body. The parent trunk suffers; the system recoils at the first infliction of the injury, but subsequently arouses itself to a reparatory effort—at times with such energy as to destroy its own vitality. The separated limb, like the branch, is given up, uncontrolled, to new affinities; and putrefaction soon reduces the mass to a state in which its previously admirable organization is no longer perceptible. Some of the lower classes of animals may, indeed, be divided with impunity; and with no other effect than that of multiplying the animal in proportion to the number of sections; but these cases are exceptions; and we may regard the destructive process—set up when parts of organized bodies are separated—as one of the best modes of distinction between the inorganic and the organized classes.

5. *Texture.*—In this respect the inorganic and the organized differ considerably—a difference which has given rise to their respective appellations. To the structure of the latter class only can the term *texture* be with propriety applied. If we examine a vegetable or animal substance with attention, we find that it has a regular and determinate arrangement or structure; and readily discover that it consists of various parts;—in the vegetable, of wood, bark, leaves, roots, flowers,

&c.; and in the animal, of muscles, nerves, vessels, &c.; all of which appear to be instruments or *organs* for special purposes in the economy. Hence, the body is said to be *organized*, and the result, as well as the process, is often called *organization*. Properly, *organization* means the process by which an organized being is formed; *organism*, the result of such process, or organic structure.

The particles of matter in an organized body, in many instances, constitute fibres, which interlace and intersect each other in all directions, and form a spongy areolar texture or tissue, of which the various organs of the body are composed. These fibres, and indeed every organized structure, are considered by modern histologists to be formed originally from cellgerms or cytoblasts: the resulting cells assuming an arrangement appropriate to the particular tissue. "A texture," says Mr. Goodsir,[1] "may be considered either by itself, or in connexion with the parts which usually accompany it. These subsidiary parts may be entirely removed without interfering with the anatomical constitution of the texture. It is essentially non-vascular;—neither vessels nor nerves entering into its intimate structure. It possesses in itself those powers by which it is nourished, produces its kind, and performs the actions for which it is destined, the subsidiary or superadded parts supplying it with materials, which it appropriates by its own inherent powers, or connecting it in sympathetic and harmonious action with other parts of the organism to which it belongs. In none of the textures are these characters more distinctly seen than in the osseous. A well-macerated bone is one of the most easily made, and at the same time one of the most curious of anatomical preparations. It is a perfect example of a texture completely isolated; the vessels, nerves, membranes, and fat, are all separated; and nothing is left but the non-vascular osseous substance."

In the inorganic substance the mass is homogeneous; the smallest particle of marble consists of carbonic acid and lime; and all the particles concur alike in its formation and preservation.

Lastly, while an inorganic body, of a determinate species, has always a fixed composition, the living being, although constituting a particular species, may present individual differences, which give rise, in the animal, to various *temperaments*, *constitutions*, *&c.*

6. *Mode of preservation.*—Preservation of the species is, in organized bodies, the effect of reproduction. As regards individual preservation, that of the mineral is dependent upon the same actions that effected its formation; on the persistence of the affinities of cohesion and combination that united its various particles. The animal and the vegetable, on the other hand, are maintained by a mechanism peculiar to themselves. From the bodies surrounding them they lay hold of nutritious matter, which, by a process of elaboration, they assimilate to their own composition; at the same time, they are constantly absorbing or taking up particles of their own structure, and throwing them off. The actions of composition and decomposition are constant whilst life

[1] Anatomical and Pathological Observations, p. 64, Edinburgh, 1845. See also Schwann, Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants; translated by Henry Smith. Sydenham Society edit. Lond. 1847.

persists; although subject to particular modifications at different periods of existence, and under different circumstances.

Again:—the inorganic and organized are alike subject to changes during their existence; but the character of these changes, in the two classes, differs essentially. The mineral retains its form, unless acted upon by some mechanical or chemical force. Within, all the particles are at rest, and no internal force exists, which can subject them to modification. There is no succession of conditions that can be termed *ages*. How different is the case with organized bodies! Internally, there is no rest; from birth till death all is in a state of activity. The plant and the animal are subject to incessant changes. Each runs through a succession of conditions or *ages*. We see it successively develope its structure and functions, attain maturity, and finally decay.

Characteristic differences likewise exist in the external conformation of the beings of the two divisions, as well as in their mode of increase. Inorganic bodies have no covering to defend them; no exterior envelope to preserve their form; a stone is the same at its centre as at its circumference; whilst organized bodies are protected by an elastic and extensible covering, differing from the parts beneath, and inservient to valuable purposes in the economy.

Every change to which an inorganic body is liable must occur at its surface. It is there that the particles are added or abstracted when it experiences increase or diminution. Increase—for *growth* it can scarcely be termed—takes place by *accretion* or *juxtaposition*, that is, by the successive application of fresh particles upon those that form the nucleus; and diminution in bulk is produced by the removal of the external layers or particles. In organized substances, increase or growth is caused by particles deposited internally, and diminution by particles subtracted from within. We see them, likewise, under two conditions, to which there is nothing similar in the mineral kingdom—*health*, and *disease*. In the former, the functions are executed with freedom and energy; in the latter, with oppression and restraint.

7. *Termination.*—Every body, inorganic or organized, may cease to exist, but the mode of cessation varies greatly in the two classes. The mineral is broken down by mechanical violence; or it ceases to exist in consequence of modifications in the affinities, which held it concrete. It has no fixed duration; and its existence may be terminated at any moment, when the circumstances, that retained it in aggregation, are destroyed. The vegetable and the animal, on the other hand, carry on their functions for a period only which is fixed and determinate for each species. For a time, new particles are deposited internally. The bulk is augmented, and the external envelope distended, until maturity or full developement is attained; but, after this, decay commences; the functions are exerted with gradually diminishing energy; the fluids decrease in quantity; and the solids become more rigid—circumstances premonitory of the cessation of vitality. This term of duration is different in different species. Whilst many of the lower classes of animals and vegetables have but an ephemeral existence, some of the more elevated individuals of the two kingdoms outlive a century.

8. *Motive forces.*—Lastly, observation has satisfactorily proved, that there are certain forces, which affect matter in general, inorganic as well

as organized; and that, in addition to these, organized bodies possess a peculiar force or forces, which modify them in a remarkable manner. Hence, we have *general forces;* and *special* or *vital;* the *first* acting upon all matter, the dead and the living, and including the forces of *gravitation*, *cohesion*, *chemical affinity*, &c.; the *latter* appertaining exclusively to living beings.

Such are the chief distinctions to be drawn between the two great divisions of natural bodies; the inorganic and the organized. By the comparison which has been instituted, the objects of physiology have been indicated. To inquire into the mode in which a living being is *born*, *nourished*, *reproduced*, and *dies*, is the legitimate object of the science. We have, however, entered only into a comparison between the inorganic and the organized. The two divisions constituting the latter class differ also materially from each other. Into these differences we shall now inquire.

2. DIFFERENCE BETWEEN ANIMALS AND VEGETABLES.

The distinctions between the divisions of organized bodies are not so rigidly fixed, or so readily appreciated, as those between the inorganic and the organized. There are certain functions possessed by both; hence called *vegetative*, *plastic*, or *organic*,—nutrition and reproduction, for example; but vegetables are endowed with these only. All organized bodies must have the power of assimilating foreign matters to their own substance, and of producing a living being similar to themselves; otherwise, the species, having a limited duration, would perish. In addition to these common functions, animals have *sensation* and *voluntary* motion; by the possession of which they are said to be *animated*. Hence, they are termed *animals*, and the condition is called *animality*. This division of the functions into *animal* and *organic* has been adopted, with more or less modification, by most physiologists.

Between animals and vegetables, situate high in their respective scales, no confusion can exist. The characters are obvious at sight. No one can confound the horse with the oak; the butterfly with the potato. It is on the lower confines of the two kingdoms that we are liable to be deceived. Many of the zoophytes have alternately been considered vegetable and animal; but we are generally able to classify any doubtful substance with accuracy; and the following are the principal points of difference.

1. *Composition.*—It was long supposed, that the essential difference between animal and vegetable substances consists in the former containing nitrogen; whilst the latter do not.[1] Modern researches have, however, satisfactorily shown, that the organized portions of animals and vegetables are essentially alike; and consist of the four elements,—carbon, oxygen, hydrogen, and nitrogen; whilst the unorganized—as the fat of the animal, and the starch of the vegetable—are composed of three elements only—carbon, oxygen, and hydrogen. Still, their intimate composition must vary greatly; for, when burning, the animal substance is readily known from the vegetable;—a fact, which, as Dr. Fleming[2] has remarked, is interesting to the young naturalist, if uncer-

[1] Brachet still adheres to this distinction. Physiologie Élémentaire de l'Homme, 2de édit., i. 21. Paris et Lyon, 1855.

[2] Philosophy of Zoology, i. 41. Edinburgh, 1822.

tain to which kingdom to refer any substance met with in his researches. The smell of a burnt sponge, of coral, or other zoophytic animal, is so peculiar, that it can scarcely be mistaken for that of a vegetable body in combustion. According to Mulder,[1] there is this real difference between plants and animals in composition, that cellulose ($C^{24}H^{21}O^{21}$) forms the principal part of the cellular mass in plants; whilst in animals the primary material is gelatin ($C^{13}H^{10}N^{2}O^{5}$); and to this rule, he says, no exception has yet been discovered either among animals or plants. Yet amylaceous or amyloid bodies—*corpora* seu *corpuscula amylacea*—of microscopic size, are found in the animal body; chiefly in the human brain and spinal marrow, in the ependyma ventriculorum and its prolongations, mingled with the proper nerve elements, and having most of the chemical characters of cellulose;[2] Mr. Busk indeed affirms, that they are absolutely identical in every property, whether optical, physical, or chemical, with starch.[3]

2. *Texture.*—In this respect, important differences are observable. Both animals and vegetables consist of solid and fluid parts. In the former, however, the fluids bear a large proportion: in the latter, the solids. This is the cause, why decomposition occurs so much more rapidly in the animal than in the vegetable; and in the succulent more than in the dry vegetable. If we analyze the structure of the vegetable, we cannot succeed in detecting more than one elementary tissue, which is *vesicular* or *areolar*, or arranged in vesicles or areolæ, and appears to form every organ of the body; whilst, in the animal, we discover at least three of these anatomical elements, the *areolar*—analogous to that of the vegetable;—the *muscular*, and the *nervous*. The vegetable again has no great splanchnic cavities containing the chief organs of the body. It has a smaller number of organs, and none that are destined for sensation or volition; in other words, no brain, no nerves, no muscular system; and the organs of which it consists are simple, and readily convertible into each other.

But these differences in organization, striking as they may appear, are not sufficient for rigid discrimination, as they are applicable only to the upper classes of each kingdom. In many vegetables, the fluids appear to preponderate over the solids; numerous animals are devoid of muscular and nervous tissues, and apparently of vessels and distinct organs; whilst MM. Dutrochet,[4] Brachet,[5] and others,[6] admit the existence of a rudimental nervous system even in vegetables.

[1] The Chemistry of Animal and Vegetable Physiology; translated by Fromberg, p. 91. Edinburgh and London, 1849.

[2] Virchow, Archiv. für pathol. Anat., &c. Leipzig, 1853. Translated in Quarterly Journal of Microscopic Science, July, 1855, p. 284.—Kölliker, Mikroskopische Anatomie, ii. 501. Leipzig, 1850. And the translation of the same by Messrs. Busk and Huxley, Sydenham Society edition, i. 458. London, 1853. And American edition, the same, by J. Da Costa, M. D., p. 402. Philadelphia, 1854.—Thos. Albert Carter, Edinb. Med. Journ., August, 1853, p. 130, On the Diffusion of Starch-corpuscles in the Animal Tissues.

[3] Quarterly Journal of Microscopical Science, January 1854.

[4] Recherches Anatomiques et Physiologiques sur la Structure Intime des Animaux, et des Végétaux, et sur leur Motilité. Paris, 1824.

[5] Recherches Expérimentales sur les Fonctions du Système Nerveux Ganglionnaire, &c., 2de édit. Paris et Lyon, 1837. And Physiologie Elémentaire de l'Homme, 2de édit., i. 64. Paris et Lyon, 1855.

[6] Sir J. E. Smith, Introduction to Botany, 7th edit., by Sir W. J. Hooker, p. 40. London, 1833.

3. *Sensation and voluntary motion.*—There is one manifest distinction between animals and vegetables. Whilst the latter receive their nutrition from the objects around them—irresistibly and without volition, or the participation of mind; and whilst the function of reproduction is effected without the union of the sexes, both volition and sensation are necessary for the nutrition of the former, and for acts that are requisite for the reproduction of the species. Hence, the necessity of two faculties or functions in the animal, that are wanting in the vegetable,—*sensibility*, or the faculty of consciousness and feeling; and *motility*, or the power of moving at will the whole body or any of its parts. Vegetables are possessed of *spontaneous*, but not of *voluntary* motion. Of the former we have numerous examples in the direction of the branches and upper surfaces of the leaves, although repeatedly disturbed, to the light; and in the unfolding and closing of flowers at stated periods of the day. This, however, is distinct from the sensibility and motility that characterize the animal. By *sensibility* man feels his own existence—becomes acquainted with the universe—appreciates the bodies that compose it; and experiences all the desires and inward feelings that solicit him to the performance of those external actions, which are requisite for his preservation as an individual, and as a species; and by *motility* he executes those external actions which his sensibility may suggest to him.

By some naturalists it has been maintained, that those plants, which are borne about on the waves, and fructify in that situation, exhibit examples of the locomotility, which is described as characteristic of the animal. One of the most interesting novelties in the monotonous occurrences of a voyage across the Atlantic towards the Gulf of Florida is the almost interminable quantity of *Fucus natans*, *Florida weed* or *Gulf weed*, with which the surface of the ocean is covered. But how different is this from the locomotion of animals! It is a subtlety to conceive them identical. The weed is passively and unconsciously borne whithersoever the winds and the waves may urge it; whilst animal locomotion requires the direct agency of volition, of a nervous system that can excite, and of muscles that can act under such excitement.

The *spontaneity* and *perceptivity* of plants must also be explained in a different manner from the elevated function of sensibility on which we shall have to dwell. These properties must be referred to the fact of certain vegetables being possessed of the faculty of contracting on the application of a stimulus, independently of sensation or consciousness. If we touch the leaf of the sensitive plant, *Mimosa pudica*, the various leaflets collapse in rapid succession. In the barberry bush, *Berberis vulgaris*, we have another example of the possession of this faculty. In the flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament, near the bottom. The susceptibility of this part is such, that the filament immediately contracts, and strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this result, provided no concussion be given to the whole. After a while, the filament retires gradually, and may be again stimulated; and when each petal, with its annexed filament, has fallen to the ground, the latter, on being touched, shows as much sensibility as ever.[1]

These singular effects are produced by the power of *contractility* or *irritability*, the nature of which will fall under consideration hereafter. It is possessed equally by animals and vegetables, and is essentially organic and vital. This power, we shall see, needs not the intervention of volition; it is constantly exerted in the animal without consciousness, and therefore necessarily without volition. Its existence in vegetables does not, consequently, demonstrate that they are possessed of consciousness.

4. *Nutrition.*—A great difference exists between plants and animals in this respect. The plant, being fixed to the soil, cannot search after food. It must be passive; and obtain its supplies from the materials around, and in contact with it; and the absorbing vessels of nutrition must necessarily open on its exterior. In the animal, on the other hand, the aliment is scarcely ever found in a state fit for absorption; it is crude, and in general—Ehrenberg[2] thinks always—requires to be received into a central organ or *stomach*, for the purpose of undergoing changes, by a process termed *digestion*, which adapts it for the nutrition of the individual. The absorbing vessels of nutrition arise, in this case, from the internal or lining membrane of the alimentary tube. The analogy that exists between these two kinds of absorption is great, and had not escaped the attention of the ancients:—*Quemadmodum terra arboribus, ita animalibus ventriculus sicut humus*" was an aphoristic expression of universal reception. With similar feelings, Boerhaave asserts, that animals have their *roots* of nutrition in their intestines; and Dr. Alston[3] has fancifully termed a plant an *inverted animal.*

After all, however, the most essential difference consists in the steps that are preliminary to the reception of food. These, in the animal, are voluntary—requiring prehension; often locomotion; and always consciousness.

5. *Reproduction.*—In this function we find a striking analogy between animals and vegetables; but differences exist, which must be referred to the same cause that produced many of the distinctions already pointed out,—the possession, by the animal, of sensibility and locomotility. For example, every part of the generative act, as before remarked, is, in the vegetable, without the perception or volition of the being:—the union of the sexes, fecundation, and the birth of the new individual are alike automatic. In the animal, on the other hand, the approximation of the sexes is always voluntary, and effected consciously:—the birth of the new individual being not only perceived, but somewhat aided by volition. Fecundation alone is involuntary and irresistible.

Again, in the vegetable the sexual organs do not exist at an early period; and are not developed until reproduction is practicable. They

[1] Sir J. E. Smith's Introduction to Botany, p. 325.

[2] Edinb. New Philosophical Journal, for Sept., 1831; and Jan., 1838, p. 232.

[3] Tirocinium Botanicum Edinburgense, 8vo., Edinb., 1753.

are capable of acting for once only, and perish after fecundation; and if the plant be vivacious, they fall off after each reproduction, and are annually renewed. In the animal, on the contrary, they exist from the earliest period of fœtal development, survive repeated fecundations, and continue during the life of the individual.

Lastly, the possession of sensibility and locomotility leads to other characteristics of animated beings. These functions are incapable of constant, unremitting exertion. *Sleep*, therefore, becomes necessary. The animal is also capable of *expression*, or of *language*, in a degree proportionate to the extent of his sensibility, and of his power over the beings that surround him.

But these differences in function are not so discriminate as they may appear at first. There are many animals, that are as irresistibly attached to the soil as the vegetables themselves. Like the latter, they must, of necessity, be compelled to absorb their food in the state in which it is presented to them. Sensibility and locomotility appear, in the zoophyte, to be no more necessary than in the vegetable. No nervous, no muscular system is required; and, accordingly, none can be traced in them; whilst many of those spontaneous motions of the vegetable, to which allusion has been made, have been considered by some to indicate the first rudiments of sensibility and locomotility; and Linnæus[1] has regarded the closure of the flowers towards night as the *sleep*, and the movements of vegetables, for the approximation of the sexual organs, as the *marriage*, of plants.

II. GENERAL PHYSIOLOGY OF MAN.[2]

The observations made on the differences between animals and vegetables have anticipated many topics, that would require consideration under this head. The general properties, which man possesses along with other animals, have been referred to in a cursory manner. They will now demand a more special investigation.

1. MATERIAL COMPOSITION OF MAN.

The detailed study of human organization is the province of the anatomist—of its intimate composition, that of the chemist. In explaining the functions executed by the various organs, the physiologist will frequently have occasion to trench upon both.

The *bones*, in the aggregate, form the *skeleton*. The base of the skeleton is a series of *vertebræ*, with the *skull* as a capital—itself regarded as a vertebra. This base is situate on the median line through the whole trunk, and contains a cavity, in which are lodged the brain and spinal marrow. On each side of this, other bones, which by some have been called *appendices*, are arranged in pairs. Upon the skeleton are placed *muscles*, for moving the different parts of the body; and for changing its situation with regard to the soil. The body is divided into *trunk* and *limbs*. The *trunk*, which is the principal portion, is composed of three *splanchnic* cavities, the *abdomen*, *thorax*, and *head*,

[1] Amœnit. Academ., tom. iv.

[2] See, on all this subject, Robin and Verdeil, Traité de Chimie Anatomique et Physiologique, &c. Paris 1853.

situate one above the other. They contain the most important organs of the body—those that effect the functions of sensibility, digestion, respiration, circulation, &c. The *head* comprises the *face*, in which are the organs of four of the senses—sight, hearing, smell, and taste,—and the *cranium*, which lodges the brain—the organ of the mental manifestations, and the most elevated part of the nervous system. The *thorax* or *chest* contains the lungs—organs of respiration—and the heart, the central organ of the circulation. The *abdomen* contains the principal organs of digestion, and (if we include in it the *pelvis*), those of the urinary secretion and of generation. Of the *limbs*, the *upper*, suspended on each side of the thorax, are instruments of prehension; and are terminated by the hand, the great organ of touch. The *lower* are beneath the trunk; and are agents for supporting the body, and for locomotion. *Vessels*, emanating from the heart, are distributed to every part—conveying to them the blood necessary for their life and nutrition: these are the *arteries*. Other vessels communicate with them, and convey the blood back to the heart—the *veins;* whilst a third set arise in the tissues, and convey into the circulation, by a particular channel, a fluid called *lymph*—whence they derive the name *lymphatics*. *Nerves*, communicating with the great central masses of the nervous system, are distributed to every part; and lastly, a membrane or layer, possessed of acute sensibility—the *skin*—serves as an outer envelope to the whole body.

It was before observed, that two kinds of *elements* enter into the composition of the body—the *chemical* or *inorganic;* and the *organic*, which are *compound*, and formed only under the force of life.

The chief CHEMICAL OR INORGANIC ELEMENTS met with are: oxygen, hydrogen, carbon, nitrogen, phosphorus, calcium; and, in smaller quantity, sulphur, iron, manganese, calcium, silicium, aluminium, chlorine; also, sodium, magnesium, &c. &c.

1. *Oxygen.*—This is widely distributed in the solids and fluids; and a constant supply of it from the atmosphere is indispensable to animal life. It is almost always found combined with other bodies; often in the form of carbonic acid,—that is, united with carbon. In a separate state it is met with in the air-bag of fishes, in which it is found varying in quantity, according to the species, and the depth at which the fish has been caught.

2. *Hydrogen.*—This gas occurs universally in the animal kingdom. It is a constituent of all the fluids, and of many of the solids; and is generally in a state of combination with carbon. In the human intestines it has been found pure, as well as combined with carbon and sulphur.

3. *Carbon.*—This substance is met with under various forms, in both fluids and solids. It is most frequently found under that of carbonic acid. Carbonic acid has been detected in an uncombined state in urine by Prout; and in the blood by Vogel.[1] It exists in the intestines of animals; but is chiefly met with in animal bodies, in combination with the alkalies or earths; and is emitted by all animals in the act of respiration.

[1] Annals of Philosophy, vii. 56.

4. *Nitrogen.*—This gas is likewise widely distributed as a component of animal substances, and especially of the tissues. It occurs in an uncombined state, in the swimming-bladder of certain fishes.

5. *Phosphorus* is an essential constituent of neurine; and is found united with oxygen, in the state of *phosphoric acid*, in many of the solids and fluids. It is this acid that is combined with the earthy matter of bones; and with potassa, soda, ammonia, and magnesia, in other parts. It is supposed to give rise to the luminousness of certain animals—as of the fire-fly, *Pyrosoma Atlanticum*, &c.—but nothing precise is known on this subject.

6. *Calcium.*—This metal is found in the animal economy in the state of oxide—lime; and it is generally united with phosphoric or carbonic acid. It is the earth, of which the hard parts of animals are constituted.

7. *Sulphur* is not met with extensively in animal solids or fluids; nor is it often found free, but usually in combination with oxygen united to soda, potassa, or lime. It seems to be an invariable concomitant of albumen; and is found in the intestines, in the form of sulphuretted hydrogen; and as an emanation from fetid ulcers.

8. *Iron.*—This metal has been detected in the colouring matter of the blood; in bile, and in milk. In the first of these fluids it was, for a long time, considered to be in the state of phosphate or sub-phosphate. Berzelius[1] showed, that this was not the case; that the ashes of the colouring matter always yielded oxide of iron in the proportion of 1-200th of the original mass. That distinguished chemist was, however, unable to detect the condition in which the metal exists in the blood; and could not discover its presence by any of the liquid tests. Subsequently, Engelhart showed, that the fibrin and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron; whilst he could procure it from the red corpuscles by incineration. He also succeeded in proving its existence in the red corpuscles by liquid tests; and his experiments were repeated, with the same results, by Rose of Berlin.[2] In milk, iron seems to be in the state of phosphate.

9. *Manganesium* has been found in the state of oxide, along with iron, in the ashes of the hair; in bones, in gall-stones, and in the blood.

10. *Copper* and *lead.*—It was conceived by M. Devergie, that copper and lead may exist naturally in the tissues;[3] but MM. Flandin and Danger, and a commission of the Académie Royale de Médecine of Paris, were unable to confirm the existence of copper; and the results of the investigations of Professor F. de Cattanei di Momo,[4] of Pavia, seem to prove the non-existence of lead also. M. Barse, however, in a paper read before the Royal Academy of Sciences of Paris, in August, 1843, states, that he found both metals in the bodies of two

[1] Medico-Chirurgical Transact., vol. iii.

[2] Turner's Chemistry, fifth ed., p. 963. London, 1834.

[3] Bullet. de l'Académ. Royale de Médecine, 19 Févr., 1839.

[4] Annali Universali di Medicina, Aprile, 1840; cited in British and Foreign Medical Review, Jan., 1841, p. 226.

persons, to whom they could not have been given for poisons. The researches of Signor Cattanei di Momo appeared to prove that these metals do not exist in the bodies of new-born children or infants; and M. J. Rossignon has offered a solution as to the probable source of the copper, which he found not only in the blood and muscles of the dog, but in many articles of vegetable and animal food; in gelatin from bones, for example, in sorrel, chocolate, bread, coffee, succory, madder, and sugar. The ashes obtained from starch sugar yielded 4 per cent. of copper; those of gelatin, 0·03 per cent.; and those of bread, 0·005 to 0·008 per cent.[1] It is now generally considered to be present in the human liver,[2] and M. E. Millon[3] asserts, that human blood invariably contains lead, copper, silica, and manganese.

11. *Silicon.*—Silica is found in the hair, bones, blood, urine, and in urinary calculi.

12. *Chlorine.*—In combination with hydrogen, and forming *chlorohydric acid*, chlorine is met with in most of the animal fluids. It is generally united with soda. Free chlorohydric acid has also been found by Dr. Prout[4] in the stomach of the rabbit, hare, horse, calf, and dog; and he has discovered the same acid in the sour matter ejected from the stomachs of those labouring under indigestion. Mr. Children, and Messrs. Tiedemann and Gmelin,[5] made similar observations; and Professor Emmet and the author[6] found it in considerable quantity in the healthy gastric secretions of man.

13. *Fluorine.*—This simple substance has been found combined with calcium—*fluoride of calcium*—in the enamel of the teeth, bones, and urine.

14. *Sodium.*—Oxide of sodium, *soda*, forms part of all the fluids. It has never been discovered in a free state; but it is united (without an acid), to albumen. Most frequently, it is combined with chlorine, and phosphoric acid; less frequently, with lactic, carbonic, and sulphuric acids. Chloride of sodium is contained in most of the animal secretions; and from its decomposition may result the chlorohydric acid of the gastric juice, and a part of the soda of the bile and other fluids.

15. *Potassium.*—The oxide, *potassa*, is found in many animal fluids, but always united with acids—sulphuric, chlorohydric, phosphoric, &c. It is much more common in the vegetable kingdom; and hence one of its names—*vegetable alkali.*

16. *Magnesium.*—The oxide, *magnesia*, exists sparingly in bones, and in some other parts; but always in combination with phosphoric acid, and appears to be always associated with calcium.

17. *Aluminium.*—Alumina is said by Morichini to exist in the enamel of the teeth. Fourcroy and Vauquelin found it in the bones; and

[1] Lond. Med. Gaz., Dec. 1, 1843, from Gazette Médicale de Paris, and Mr. Paget, Rep. on Anatomy and Physiology, 1843–4, in Brit. and For. Med. Rev., Jan., 1845, p. 249.

[2] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 29, Philad., 1853.

[3] Comptes Rendus, Paris, 1848.

[4] Philosoph. Transact. for 1824, p. 45.

[5] Recherches Expérimentales, &c., sur la Digestion, trad. par A. G. L. Jourdan. Art. 4, p. 94. Paris, 1827.

[6] See under the head of "Digestion," and the author's Human Health, p. 191, Philadelphia, 1844.

John, in white hairs. According to Schlossberger, it is in the flesh of fishes.[1]

18. *Titanium.*—Dr. Rees affirms, that he detected it in salts obtained from the supra-renal capsules.

19. *Arsenic.*—It was asserted, by M. Orfila, that arsenic exists naturally in the human body; and that it is a normal constituent of human bones. Subsequent experiments, however, performed by M. Orfila himself, have shown that there was fallacy in his first observations.[2]

Organic Elements, *proximate principles* or *compounds of organization*, are combinations of two or more of the elementary substances, in definite proportions. Formerly, four only were admitted—*gelatin*, *fibrin*, *albumen*, and *oil*. Of late, however, organic chemistry has pointed out others, which are divided into two classes—*first*, those that contain nitrogen, as albumen, gelatin, fibrin, osmazome, mucus, casein, urea, uric acid, red colouring principle of the blood, yellow colouring principle of the bile, &c.; and *secondly*, those that do not contain nitrogen—as olein, margarin, stearin, the fatty matter of the brain and nerves, acetic, oxalic, benzoic, and lactic acids, sugar of milk, sugar of diabetes, hepatic sugar, picromel, colouring principle of the bile, and that of other solids and liquids, &c.

a. *Organic Elements that contain Nitrogen.*

1. *Protein.*—Modern researches have appeared to show, that the chief proximate principles of animal tissues, and those that have been regarded as highly nutritious among vegetables, have almost identically the same composition; and are modifications of a principle to which Mulder—its discoverer—gave the name *Protein.* If animal albumen, fibrin, or casein, be dissolved in a moderately strong solution of caustic potassa, and the solution be exposed for some time to a high temperature, these substances are decomposed. The addition of acetic acid to the solution causes, in all three, the separation of a gelatinous translucent precipitate, which has exactly the same character and composition, from whichsoever of the solutions it is obtained. It may be procured, too, from globulin of blood, and from vegetable albumen.[3]

The chemical relations of protein, especially in regard to oxygen, are full of interest. The products of its oxidation, *binoxide* and *tritoxide of protein*, occur constantly in the blood. They are formed in the lungs from fibrin; which, in a moist state, possesses the property of absorbing oxygen. Fibrin, oxidized in the lungs, is, according to Mulder, the principal—if not the only—carrier of the oxygen of the air in the blood to the tissues; and it is from this substance, especially, that the secretions are formed. In inflammatory conditions, a much larger quantity of protein, in an oxidized state, is contained in the

[1] Henle, Allgemeine Anatomie, s. 4. Leipz., 1841, or Jourdan's translation, i. 2, Paris, 1843.

[2] Rapport de l'Académie Royale de Médecine, Juillet, 1841; Taylor's Medical Jurisprudence, by Dr. Griffith, p. 133, Philada., 1845; and Simon, Animal Chemistry, Sydenham Soc. edit., p. 4, Lond., 1845, or Amer. edit., Philad., 1845.

[3] Liebig, Animal Chemistry, Gregory's and Webster's edit., p. 100. Cambridge, 1842.

blood than in health; and this, according to Mulder, gives occasion to the buffy coat.[1]

The following substances may be regarded as modifications or combinations of protein. They are composed of it and of a small quantity of phosphorus, or of sulphur, or both.[2]

a. *Albumen.*—This is one of the most common organic constituents; and appears under two forms—*liquid* and *concrete.* In its purest state, the former is met with in white of egg—whence its name; in the serum of the blood; the lymph of the absorbents; the serous fluid of the great splanchnic cavities and of the areolar membrane; and in the synovial secretion. It is colorless and transparent; without smell or taste; and is coagulated by acids, alcohol, ether, metallic solutions, infusion of galls, and by a temperature of 158° Fahrenheit. A very dilute solution, however, does not become turbid until it is boiled. It is excreted by the kidneys in large quantities, in the disease, which, owing to its presence in the urine, has been called *Albuminuria.*

Concrete, coagulated, or *solid albumen*, is white; tasteless; and elastic; insoluble in water, alcohol, or oil; but readily soluble in alkalies.

Albumen is always combined with soda. It exists in abundance—both the liquid and concrete—in different parts of the animal body. Hair, nails, and horn, consist of it; and it is, in some form or other, a constituent of many tumours.

In the advanced chyliferous vessels albumen is found in quantity; and it is probable that every proteinaceous aliment, and perhaps those that are not proteinaceous, is reduced to the form of albumen in the process of digestion, so that it becomes the nutritious constituent of whatever fluid is absorbed for the formation of tissue.

Albuminose or *peptone* has considerable analogy with albumen and casein. Its non-coagulation by heat distinguishes it from the former; the precipitate which it forms with acetic acid, and which redissolves in an excess of the acid, distinguishes it from the latter. It is found in the chyme from the digestion of nitrogenized matters; and passes into the blood, where it is found in the proportion of from four to six parts in the 1,000.[3]

b. *Fibrin.*—This proximate principle exists in the chyle; enters into the composition of the blood; forms the chief part of muscular flesh; and may be looked upon as one of the most abundant animal substances. It is obtained by beating the blood with a rod, as it issues from a vein. The fibrin attaches itself to each twig in the form of red filaments, which may be deprived of their colour by repeated washing with cold water. Fibrin is solid; white; flexible; slightly elastic; insipid; inodorous; and heavier than water. It is neither soluble in water, alcohol, nor acids; dissolves in liquid potassa or soda, in the cold, without much change; and, when warm, becomes decomposed.

Fibrin constitutes the buffy coat of blood; it is thrown out from the bloodvessels, as a secretion, in many cases of inflammation; and becomes subsequently organized.

[1] Simon, Animal Chemistry, Sydenham Soc. edit., p. 12, London, 1845; or American edit., Philadelphia, 1845.

[2] Henle, op. cit., p. 31.

[3] L. A. Segond, Traité d'Anatomie Générale, p. 49. Paris, 1854.

There is no mode of distinguishing liquid fibrin from liquid albumen, except by the spontaneous coagulation of the former. Consequently, according to Henle,[1] if a liquid does not coagulate of itself, it does not contain fibrin. A very small quantity, however, of fibrin may be so dissolved in serous fluid, that it will not coagulate.[2] The change of albumen to fibrin has generally been regarded as the first important step in the process of assimilation, fibrin being endowed with much higher organizable properties than albumen. This has been attributed to some influence exerted upon albuminous fluids by the living surfaces over which they pass, but reasons have been brought forward for the belief, that it is rather in a state of transition towards the fibro-gelatinous textures than towards those of the cellulo-albuminous type; and Dr. Carpenter,[3] who was a strenuous supporter of the former doctrine, now maintains the latter: and thinks, that we seem to be justified in regarding fibrin as the special pabulum of those connective or gelatinous tissues whose physical offices in the economy are so important, whilst their vital endowments are so low—a view which the author is, as yet, by no means prepared to adopt.

More probable is that of Mr. Simon,[4] that the fibrin of the blood may have arisen in it from its own decay, or have reverted to it from the waste of the tissues; when, amongst other reasons, we consider the small quantity of fibrin in the blood, so inadequate, apparently, for the purposes of nutrition, and that its amount is not diminished by bloodletting, or by starvation; but, on the contrary, has been observed to be greatly increased under such circumstances.

The correspondence of fibrin with albumen is shown by the circumstance, that it may be wholly dissolved in a solution of nitrate of potassa, and that this solution greatly resembles a solution of albumen, and is coagulable by heat. This happens, however, only to the ordinary fibrin of venous blood. That which is obtained from arterial blood or from the buffy coat; or which has been exposed for some time to the air, is not thus soluble, the difference appearing to depend upon the larger quantity of oxygen contained in the latter; for a solution of venous fibrin in nitre, contained in a deep cylindrical jar, allows a precipitate in fine flocks to fall gradually, provided the air has access to the surface; but not if its access be prevented. This precipitate is insoluble in the solution of nitre, and possesses the properties of arterial fibrin.[5] Hence, Dr. Carpenter[6] has remarked, it might be inferred, that the fibrin of venous blood most nearly resembles albumen; whilst that of arterial blood, and of the buffy coat, contains more oxygen, and is more highly animalized [?]; and that the matter of the red corpuscles is not the only constituent of the blood, which undergoes a change in the respiratory process.

c. *Casein*, *Caseum*, *Caseous matter*.—This substance exists in greatest

[1] Op. cit., p. 38.

[2] Dr. Buchanan, Lond. Med. Gaz. for 1836, pp. 52 and 90, and ibid. for 1845, p. 617.

[3] Principles of Human Physiology, Amer. edit., p. 216. Philad., 1855.

[4] Lectures on General Pathology, Amer. edit., p. 45. Philad., 1852.

[5] Scherer, Chemisch-physiologische Untersuchungen, Annalen der Chemie, &c., Oct. 1841, cited in Graham's Chemistry, Amer. edit., p. 692. Philad., 1843.

[6] Principles of Human Physiology, 2d edit., p. 479. Philad., 1845.

abundance in milk; and is the basis of cheese. It is found also in blood, saliva, bile, pancreatic juice; in pus, tubercular matter, &c. To obtain it, milk must be left at rest, at the ordinary temperature, until it is coagulated; the cream that collects on the surface must be taken off; the clot well washed with water, drained upon a filter, and dried. The residuum is pure *casein.* It is a white, insipid, inodorous substance, insoluble in water, but readily soluble in the alkalies, especially in ammonia. It possesses considerable analogy with albumen. Prout ascribes the characteristic flavor of cheese to the presence of caseate of ammonia.

Until recently it was believed that vegetable albumen and fibrin differ from animal albumen and fibrin; but Mulder showed that this is not the case; and casein, which agrees with the others in composition, has been found by Liebig in the vegetable. *Legumin* is vegetable casein. Of late, the views of Mulder as to the very existence of protein have, however, been combated by Liebig and Th. Fleitmann and others;[1] but still—as Messrs. Kirkes and Paget[2] have remarked—there seems sufficient probability in those views to justify the received use of the term "*protein compounds*," in speaking of the class, including fibrin, albumen, and others, to which the name of "*albuminous compounds*" was formerly applied.

2. *Globulin.*—The globulin of Berzelius consists of the envelopes of the blood corpuscles, and of the part of their contents that remains after the extraction of the hæmatin. The two constitute *hæmatoglobulin.* M. Lecanu regards globulin as identical with albumen; according to Mulder, it belongs to the combinations of protein. Simon terms it *blood casein*, and Henle[3] thinks it probable, that it is in reality only albumen with the membranes of the blood corpuscles. Berzelius considers the crystalline lens to be composed of the same substance.

3. *Pepsin.*—This substance, to which Eberle gave the name, was discovered by Schwann. It seems to be a modification of protein, but has not been much examined. It is contained in the gastric juice; and its physiological properties will be described under the head of DIGESTION. It greatly resembles albumen; coagulates by heat and alcohol; and loses its solvent virtues. It is best procured by digesting portions of the mucous membrane of the stomach in cold water, after they have been macerated for some time in water at a temperature between 80° and 100° of Fahrenheit. The warm water dissolves various substances as well as some of the pepsin; but the cold water takes up little more than the pepsin, which is obtained, by evaporating the cold solution, in the form of a grayish-brown viscid fluid. The addition of alcohol throws down the pepsin in grayish-white flocculi; and one part of the principle thus prepared, when dissolved in even 60,000 parts of water, will digest meat and other alimentary substances. Liebig doubts the existence of pepsin as a distinct compound. Ac-

[1] Scherer, in Canstatt und Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1847, s. 82. Erlangen, 1848. "Cette substance générale," says Brachet, "adoptée en Allemagne, est encore une problème." Physiologie Élémentaire de l'Homme, 2de édit., Paris et Lyon, 1855.

[2] Manual of Physiology, 2d Amer. edit., p. 24, Philad., 1853.

[3] Op. cit., p. 53.

cording to him—as explained hereafter—the solvent power of the gastric juice is owing to the gradual decomposition of a matter dissolved from the lining membrane of the stomach, aided by oxygen introduced into the saliva.

4. *Gelatin.*—This is the chief constituent of areolar tissue, skin, tendons, ligaments, and cartilages. The membranes and bones also contain a large quantity of it. It is obtained by boiling these substances for some time in water; clarifying the concentrated solution; allowing it to cool, and drying the substance, thus obtained, in the air. In this state it is called *glue;* in a more liquid form, *jelly.* Gelatin dissolves readily in hot water; is soluble in acids and alkalies; insoluble in alcohol, ether, and in fixed and volatile oils. Alcohol precipitates it from its solution in water. It is not a compound of protein; hence it has been concluded, that it cannot yield albumen, fibrin, or casein; and, therefore, that blood cannot be formed of it. The animal system, it has been maintained, can convert one form of protein into another, but cannot form protein from compounds that do not contain it. This deduction—as stated hereafter—is probably too hasty. It is admitted, that gelatin may be produced from fibrin and albumen; since, in animals that are fed on these alone, the nutrition of the gelatinous tissues does not seem to be impaired; and it is as easy to conceive that gelatin may go to the formation of the proteinaceous tissues.

Gelatin, nearly in a pure state, forms the air-bag of different fishes, and is well known under the name of *isinglass.* It is used extensively in the arts, on account of its adhesive quality, under the forms of *glue* and *size.* What is called *portable soup* is dried jelly, seasoned with various spices.

5. *Chondrin.*—This was first discovered by J. Müller. It is obtained by boiling the cornea, the permanent cartilages, and the bones before ossification. It is a variety of gelatin.

6. *Osmazome.*—This is the *matière extractive du bouillon; extractive, and saponaceous extract of meat.*—When flesh, cut into small fragments, is macerated in successive portions of cold water, the albumen, osmazome, and salts are dissolved; and, on boiling the solution, the albumen is coagulated. From the liquid remaining, the osmazome may be procured in a separate state, by evaporating to the consistence of an extract, and treating with cold alcohol. This substance is of a reddish-brown colour; and is distinguished from the other animal principles by solubility in water and alcohol—whether cold or at the boiling point—and by not forming a jelly when its solution is concentrated by evaporation.

Osmazome exists in the muscles of animals, the blood, and the brain. It gives the peculiar flavour of meat to soups; and, according to Fourcroy, the brown crust of roast meat consists of it. It is regarded as a mixture of different crystallizable and uncrystallizable principles with empyreumatic products.[1]

Kreatin and *Kreatinin* are two principles which were formerly included among the extractive or ill-defined matters of muscular tissue.

[1] Robin and Verdeil, Traité de Chimie anatomique, &c., iii. 565, Paris 1853.

They have been investigated by Liebig,[1] who discovered them also in urine. They appear to be like urea, mere products of the decomposition of muscle.

7. *Mucus.*—This term has been applied to various substances; and hence the discordant characters ascribed to it. Applying it to the fluid secreted by mucous surfaces, it varies somewhat according to the source whence it is derived. Its leading characters may be exemplified in that derived from the nostrils, which has the following properties. It is insoluble in alcohol and water, but imbibes a little of the latter, and becomes transparent; it is neither coagulated by heat, nor rendered horny; but is coagulated by tannic acid.

Mucus, in a liquid state, serves as a protecting covering to different parts. Hence it varies somewhat in its characters, according to the office it has to fulfil. When inspissated, it forms, according to some, the minute scales that are detached from the surface of the body by friction, corns, and the thick layers of the soles of the feet, nails, and horny parts; and it is contained in considerable quantity in hair, wool, feathers, scales of fishes, &c.

8. *Urea.*—This proximate principle exists in the urine of the mammalia when they are in a state of health. In human urine it is less abundant after a meal, and it may nearly disappear in diabetes, and affections of the liver. It is obtained by evaporating urine to the consistence of syrup. The syrup is then treated with four parts of alcohol, which are afterwards volatilized by heating the alcoholic extract. The mass that remains is dissolved in water, or rather in alcohol, and crystallized.

The purest urea that has been obtained, assumes the shape of acicular prisms similar to those of the muriate of strontian. It is colourless, devoid of smell, or of action on blue vegetable colours, transparent, and somewhat hard. Its taste is cool, slightly sharp, and its specific gravity is greater than that of water.

Urea is supposed by Dr. Prout to be chiefly derived from the decomposition of the gelatinous tissues; but, as Dr. Carpenter has remarked,[2] there seems to be no valid reason thus to limit the mode of its production.

9. *Uric* or *lithic acid.*—This acid is found in the urine of man, birds, serpents, tortoises, crocodiles, lizards; in the excrements of the silkworm, and very frequently in urinary calculi. It is obtained by dissolving any urinary calculus which contains it, or the sediment of human urine, in warm liquid potassa, and precipitating the uric acid by the chlorohydric. Pure uric acid is white, tasteless, and inodorous. It is insoluble in alcohol, and is dissolved very sparingly by cold or hot water, requiring about 10,000 times its weight of that fluid, at 60° of Fahrenheit, for solution. According to Dr. Prout, this acid is not free, but is commonly combined with ammonia; the reddening of litmus paper being not altogether owing to it, but to the super-phosphate of ammonia, which is likewise present in urine.

In the herbivora, this acid is replaced by the hippuric. *Xanthic acid*, found by Marcet in urinary calculi, seems to have been uric acid.

[1] Chemistry of Food, London, 1847.
[2] Human Physiology, § 673, Lond., 1842.

10. *Colouring principles of the blood.*—It has been already observed that Engelhart and Rose, German chemists, had detected iron in the red corpuscles of the blood, but had not found it in the other principles of that fluid. It has been considered probable, therefore, that it has something to do with the colour. Engelhart's experiments did not, however, determine the manner in which it acts, nor in what state it exists in the blood. The sulphocyanic acid which is found in the saliva forms, with peroxide of iron, a colour exactly like that of venous blood; and it is possible, that the colouring matter may be a sulphocyanate of iron.

To obtain the red colouring matter, *hæmatin* or *hæmatosin*, allow the crassamentum or clot, cut into thin pieces, to drain as much as possible on bibulous paper, triturating it with water, and then evaporating the solution at a temperature not exceeding 122° of Fahrenheit. When thus prepared, the colouring particles are no longer of a bright red colour, and their nature is somewhat modified, in consequence of which they are insoluble in water. When half dried, they form a brownish-red, granular, friable mass; and when completely dried at a temperature between 167° and 190°, the mass is tough, hard, and brilliant. The mode in which the hæmatin is concerned in the coloration of the blood, will be inquired into under the head of RESPIRATION.

A brown colouring matter, *hæmaphæin*, and a blue colouring matter, *hæmacyanin*, have been described. The former, however, it has been suggested, is nothing more than hæmatin modified by an alkali; and Simon[1] never succeeded in detecting the latter.

11. *Yellow colouring principle of the bile;—cholepyrrhin* of Berzelius, *biliphæin* of Simon.—This substance is present in the bile of nearly all animals. It enters into the composition of almost all gall-stones, and is deposited in the gall-bladder under the form of magma. It is solid; pulverulent; when dry, insipid, inodorous, and heavier than water. When decomposed by heat, it yields carbonate of ammonia, charcoal, &c. It is insoluble in water, alcohol, and the oils; but soluble in alkalies. On the gradual addition of nitric acid to a fluid, which contains this substance in solution, a very characteristic series of tints is evolved. The fluid becomes first blue, then green, afterwards violet and red, and ultimately assumes a yellow or yellowish-brown colour.

On adding an acid to a solution of biliphæin, a precipitation of green flocculi takes place: these possess all the properties of chlorophyll, or the green colouring matter of leaves. In this state it is termed *biliverdin* by Berzelius; and is a product of the metamorphosis of biliphæin.[2]

These are the chief nitrogenized organic elements.

b. *Organic Elements that do not contain Nitrogen.*

1. *Olein* and *Stearin.*—Fixed oils and fats are not pure proximate principles, as was at one time supposed. They were long presumed to consist of two substances, one of which is solid at the ordinary temperature of the atmosphere, and the other fluid: the former of these

[1] Op. cit., p. 42.

[2] Simon, op. cit., p. 44.

was called *Stearin*, from στεαρ, suet; the latter, *Elain* or *Olein*, from ελαιον, oil. Stearin is the chief ingredient of vegetable and animal suet; of fat and butter; and is found, although in small quantity, in fixed oils. In suety bodies, it is the cause of their solidity. Elain and stearin may be separated from each other by exposing fixed oil to a low temperature; and pressing it, when congealed, between folds of bibulous paper. The stearin is thus obtained in a separate form; and by pressing the bibulous paper under water, an oily matter is procured, which is elain in a state of purity. Modern chemistry has shown, however, that fat contained in the cells of adipose tissue is composed of a base termed *glycerin*—itself hydrated oxide of glyceryl—with *stearic* and *margaric acids*. Stearin is a *bi-stearate of glycerin*:—olein, or elain, an *oleate of glycerin*.

2. *Fatty matter of the Brain and Nerves.*—Vauquelin[1] found two varieties of fatty matter in the brain—the one white, the other red, the properties of which have not been fully investigated. Both give rise to phosphoric acid by calcination, without there being any evidence of an acid or phosphate in their composition. They may be obtained by repeatedly boiling the cerebral substance in alcohol; filtering each time; mixing the various liquors, and suffering them to cool:—a lamellated substance is deposited, which is the *white fatty matter*. By evaporating the alcohol, which still contains red fatty matter and osmazome, to the consistence of *bouillie;* and exposing this, when cold, to the action of alcohol, the osmazome is entirely dissolved, whilst the alcohol takes up scarcely any *red fatty matter*.

3. *Acetic acid.*—This acid exists in a very sensible manner in sweat, urine, and milk—even when entirely sweet. It, or lactic acid, is formed in the stomach in indigestion; was found by the author and his late friend, Professor Emmet, contained in the gastric secretions in health, and is one of the constant products of the putrid fermentation of animal or vegetable substances. It is the most prevalent of the vegetable acids, and most easily formed artificially.

4. *Oxalic acid.*—This acid—which exists extensively in the vegetable kingdom, but always united with lime, potassa, soda, or oxide of iron—is only found, combined with lime, as an animal constituent in certain urinary calculi.

5. *Benzoic acid.*—This acid, found in many individuals of the vegetable kingdom, is likewise met with in the urine of the horse, cow, camel, and rhinoceros; and sometimes in that of man, especially of children. When benzoic acid is swallowed, hippuric acid is observed in the urine; and it was supposed by Mr. A. Ure and others, that this was owing to the conversion of uric acid into hippuric; and as the hippurates are more soluble, it was suggested by him, that benzoic acid might be advantageously exhibited in lithuria, and in cases of gouty depositions of lithate of soda. It has been found, however, by Drs. Keller and Garrod,[2] and by Professors Booth and Boyé, of Philadelphia,[3] that the administration of benzoic acid exerts no influence on the amount of uric acid in the urine.

[1] Annales de Chim., lxxxi. 37.

[2] Liebig's Animal Chemistry, p. 316.

[3] Proceedings of the American Philosophical Society at the Centennial Celebration in Philada., May, 1843, and Transactions of the A. P. Society, vol. ix. pt. 2, Philadelphia, 1845.

6. *Lactic acid.—Acid of milk* is met with in blood, gastric juice, urine, milk, marrow, and also in muscular flesh. At times it is in a free state, but is usually united with alkalies. However much it may be concentrated, it does not crystallize, but remains under the form of syrup or extract. When cold it is tasteless, but, when heated, has a sharp acid taste. According to Dr. Prout, this acid, like urea, results from the decomposition of the gelatinous parts of the system; according to Berzelius, however, it is a general product of the spontaneous decomposition of animal matters within the body. Liebig[1] formerly denied that any lactic acid is formed in the stomach in health; and affirmed, that the property possessed by many substances, such as starch, and the varieties of sugar, by contact with animal matters in a state of decomposition, of passing into lactic acid, had induced physiologists too hastily to assume the fact of the production of lactic acid during healthy digestion:—yet he now admits its presence.

7. *Sugar of milk.*—This substance, which is so called because it has a saccharine taste, and exists chiefly, if not solely, in milk, differs from ordinary sugar in not fermenting. It is obtained by evaporating whey, formed during the making of cheese, to the consistence of honey; allowing the mass to cool; dissolving; clarifying and crystallizing. It commonly crystallizes in regular parallelopipedons, terminated by pyramids with four faces. It is white; semitransparent; hard, and of a slightly saccharine taste.

8. *Sugar of diabetes.*—In *diabetes mellitus*, the urine, which is often passed in enormous quantity, contains, at the expense of the economy, a large amount of peculiar saccharine matter, which, when properly purified, appears identical in properties and composition with vegetable sugar, and approaches nearer to the sugar of grapes—*glucose*—than to that of the cane. It is obtained in an irregularly crystalline mass, by evaporating diabetic urine to the consistence of syrup, and keeping it in a warm place for several days. It is purified by washing in cold, or—at the most—gently heated alcohol, till the liquor comes off colourless; and then dissolving it in hot alcohol. By repeated crystallization it is thus rendered pure.[2] In the notes of two cases of diabetes mellitus now before the author, it appears that sixteen ounces of the urine of one patient, of the specific gravity of 1.034, afforded a straw-coloured extract, which, when cold and consolidated, weighed one ounce and five drachms. The same quantity of the urine of the other patient, specific gravity 1.040, yielded one ounce and seven drachms. Neither extract appeared to contain urea when nitric acid was added; but when a portion was dissolved in water, and subjected to a temperature of 212°, traces of ammonia were manifested on the vapour being presented to the fumes of chlorohydric acid. From this a conclusion was drawn, that urea was present, as it is the only known animal matter decomposed by the heat of boiling water. In a little more than a month, the subject of the latter case passed about four hundred and eighty pints of urine, or about seventy-five pounds troy of diabetic sugar!

9. *Hepatic sugar, liver sugar*, found, by M. Bernard, to be produced in the liver, appears to resemble diabetic sugar more than it does glu-

[1] Op. cit., p. 107.

[2] Prout, Medico-Chirurg. Transact., viii. 538.

cose. Little is known, however, of its precise characters; but it is much more assimilable than glucose; for, when injected into the veins, but little of it is detected in the urine.[1]

10. *Bilin* or *Picromel.*—M. Thénard[2] discovered this principle in the bile of the ox, sheep, dog, cat, and several birds; Chevalier, in that of man. To obtain it, the acetate of lead of commerce must be added to bile until there is no longer any precipitate. By this means, the yellow matter of the bile and the whole of the fatty matter are thrown down, united with the oxide of lead; the phosphoric acid of the phosphate of soda, and the sulphuric acid of the sulphate of soda, are likewise precipitated. The picromel may then be thrown down from the filtered liquor by the subacetate of lead. The precipitate, which is a combination of picromel with oxide of lead, must now be washed and dissolved in acetic acid. Through this solution, sulphuretted hydrogen is passed to separate the lead; the solution is then filtered, and the acetic acid driven off by evaporation.

Pure picromel is devoid of colour, and has the same appearance and consistence as thick turpentine. Its taste is at first acrid and bitter, but afterwards sweet. Its smell is nauseous, and specific gravity greater than that of water. When digested with resin of bile, a portion of the latter is dissolved, and a solution obtained, which has a bitter and a sweet taste, and yields a precipitate with the subacetate of lead and the stronger acids. This is the compound that causes the peculiar taste of the bile.

11. *Cholesterin.*—This is a constituent principle of the blood, bile, medullary neurine, and *vernix caseosa.* It is often precipitated from bile in a crystalline state: and forms of itself concretions which have an evidently laminated texture. It has been very frequently met with in morbid secretions and tissues; in the fluid of dropsies; in that of cysts and hydatids; and in medullary fungus and other tumours. At times, it is dissolved; at others, swims upon the fluid in brilliant plates, or forms solid masses. It is obtained from biliary calculi by boiling in water, and dissolving them afterwards in boiling alcohol. On cooling, crystals of cholesterin separate.

These inorganic and organic elements—with others of less moment discovered by modern chemists—variously combined and modified by the vital force, constitute the different parts of the animal fabric.[3] Chemistry, in its present improved condition, enables us to separate them, and to investigate their properties; but all the information we derive from this source relates to bodies, that have been influenced by the vital force, but are no longer so; and in the constant mutations that occur in the system whilst life exists, and under its controlling agency, the same textures might exhibit very different chemical cha-

[1] Bernard, Leçons de Physiologie Expérimentale, &c. &c., p. 209, Paris, 1855.

[2] Mémoir. d'Arcueil, i. 23, and Traité de Chimie, tom. iii.

[3] See, on all this subject, Robin and Verdeil, Traité de Chimie Anatomique et Physiologique, &c., Paris, 1853; and Lehmann, Lehrbuch der Physiologischen Chemie, Leipz., 1852, or translation of the same, by Dr. Geo. E. Day: Amer. edit., by Dr. Robt. E. Rogers, Phila., 1855. Also, Report on the Progress of Animal Chemistry during the years 1852, 3 and 4, by Dr. Geo. E. Day, in the British and Foreign Medico-Chirurgical Review for April and July, 1855.

racteristics, could our researches be directed to them under those circumstances. Whenever, therefore, the physiologist has to apply chemical elucidations to operations of the living machine, he must recollect that all his analogies are drawn from dead matter, which differs so widely from the living as to suggest the necessity of a wise and discriminating caution.

The components of the animal body are invariably found under two forms—*solids* and *fluids*. Both are met with in every animal, the former being derived from the latter; for, from the blood every part of the body is separated; yet they are mutually dependent, for every liquid is contained in a solid. The blood itself circulates in solid vessels. Both, too, possess an analogous composition; are in constant motion, and incessantly converted from one into the other. Every animal consists of a union of the two; and this union is indispensable to life. Yet certain vague notions with regard to their relative preponderance in the economy, and to their agency in the production of disease, have led to discordant doctrines of pathology,—the *solidists* believing, that the cause of most affections is resident in the solids; the *humorists*, that we are to look for it in the fluids. In this, as in similar cases, the mean will lead to the most satisfactory result. The causes of disease ought not to be sought in the one or the other exclusively.

c. *Of the Solid Parts of the Human Body.*

A *solid* is a body whose particles adhere to each other, so that they do not separate by their own weight; but require the agency of some extraneous force to effect the disjunction. Anatomists reduce all the solids of the human body to twelve varieties;—*bone*, *cartilage*, *muscle*, *ligament*, *vessel*, *nerve*, *ganglion*, *follicle*, *gland*, *membrane*, *areolar membrane*, and *viscus*.

1. *Bone* is the hardest of the solids. It forms the skeleton; the levers for the various muscles to act upon; and serves for the protection of important organs.

2. *Cartilage* is of a white colour, formed of very elastic tissue; covering the articular extremities of bones to facilitate their movements; sometimes added to bones to prolong them, as in the case of the ribs; at others, placed within the articulations to act as elastic cushions; and, in the fœtus, forming a substitute for bone. Hence, cartilages are divided into *articular* or *incrusting*, *cartilages of prolongation*, *interarticular cartilages*, and *cartilages of ossification*.

3. *Muscles* constitute the flesh of animals. They consist of fasciculi of contractile fibres, extending generally from one bone to another; and are the agents of all movements.

4. *Ligaments* are tough; difficult to tear; and under the form of cords or membranes, serve to connect different parts with each other, particularly bones and muscles; hence their division, by some anatomists, into *ligaments of bones*—as the ligaments of the joints; and *ligaments of muscles*—as the tendons and aponeuroses.

5. *Vessels* are solids, having the form of canals, in which the fluids

circulate. They are called—according to the fluid they convey—*sanguineous* (*arterial* and *venous*), *chyliferous*, *lymphatic*, &c.

6. *Nerves* are cords, consisting of numerous tubular fasciculi. These are connected with the brain, spinal marrow, or great sympathetic. They are the organs by which impressions are conveyed to the nervous centres, and by which each part receives from these its nervous influence. There are three great divisions of the nerves,—the *cerebro-spinal*, *true spinal*, and *organic*.

7. *Ganglions* are solid knots in the course of a nerve which seem to be formed of an inextricable interlacing of nervous filaments. The term is likewise applied, by many modern anatomists, to similar interlacings of the ramifications of lymphatic vessels. *Ganglions* may, consequently, either be *nervous* or *vascular;* and the latter, again, may be divided into *chyliferous* or *lymphatic*, according to the kind of vessel on which they appear. Chaussier, a distinguished anatomist and physiologist, has given the name *glandiform ganglions* to certain organs whose nature and functions are unknown, but which appear to be concerned in lymphosis,—as the thymus gland, the thyroid gland, &c.

8. *Follicles* or *crypts* are secretory organs, shaped—when simple—like membranous ampullæ or vesicles, formed by an inversion of the outer membranes of the body—the skin and mucous surfaces—and secreting a fluid intended to lubricate them. They are often divided into the *simple* or *isolated;* the *conglomerate;* and the *compound*, according to their size, or the manner in which they are grouped and united together.

9. *Glands* are secretory organs not differing essentially from the last. Their organization is more complex; and the fluid, after secretion, is poured out by means of one or more excretory ducts.

10. *Membrane*.—This is one of the most extensive and important of the substances formed chiefly of areolar tissue. It is spread out in the shape of a web; and, in man, serves to line cavities and reservoirs; and to form, support, and envelope organs.

Bichat divides membranes into two kinds, *simple* and *compound*, according as they are formed of one or more layers.

Simple membranes are of three kinds, *serous*, *mucous*, and *fibrous*.

1*st*. *Serous membranes* constitute all the sacs or shut cavities of the body,—those of the chest and abdomen, for example.

2*dly*. *Mucous membranes* line all the outlets of the body,—the air-passages, alimentary canal, urinary and genital organs, &c.

3*dly*. *Fibrous membranes* form tendon, aponeurosis, ligament, &c.

Compound membranes are formed by the union of the simple, and are divided into *fibro-serous*, as the pericardium; *sero-mucous*, as the gall-bladder, at its lower part; and *fibro-mucous*, as the ureter.

11. *Areolar*, *cellular* or *laminated tissue*—to be described presently—is a sort of spongy or areolar structure, which forms the framework of the solids; fills up the spaces between them, and serves at once as a bond of union and of separation.

12. A *viscus* is the most complex solid of the body; not only as regards intimate organization, but use. This name is given to organs contained in the splanchnic cavities,—brain, thorax, and abdomen,—and hence the viscera are termed *cerebral*, *thoracic*, and *abdominal*.

Every animal solid is either *amorphous* or *fibrous;* that is, it is either without apparent arrangement, like jelly; or is disposed in minute threads, called *fibres.* The disposition of these threads, in different structures, is various. Sometimes, they retain the form of threads; at others, they have that of laminæ, lamellæ, or plates. Accordingly, when we examine any animal solid, where the organization is perceptible, it is found to be either amorphous, or fibrous and laminated.

This circumstance led the ancients to endeavour to discover an *elementary fibre* or *filament*, from which the various organs might be formed. Haller[1] embraced the idea, and endeavoured to unravel every texture to this ultimate element,—which, he conceived, is to the physiologist what the line is to the geometer; and, as all figures can be constructed from the line, so every tissue and organ of the body may be built up from the *filament.* Haller, however, admitted that this elementary fibre is not capable of demonstration, and that it is visible only to the "mind's eye,"—"*invisibilis ea fibra, quam solâ mentis acie adtingimus.*" It must be regarded, indeed, as a pure abstraction; for, as different animal substances in the mass have different proportions of carbon, hydrogen, oxygen, and nitrogen, it is fair to conclude that the elementary fibre must equally differ in the different substances.

The ancients believed that the first product of the elementary fibre was areolar tissue; and that this tissue forms every organ of the body, —the difference in the appearance of the organs arising from the different degrees of condensation of its laminæ. Anatomists, however, have been unable to reduce all animal solids to areolar tissue only.

In the upper classes of animals, three *primary fibres* or *tissues* or anatomical elements are usually admitted,—the *areolar, cellular* or *laminated;* the *muscular;* and the *nervous, pulpy* or *medullary.*

1. The, *areolar, cellular, mucous, filamentous* or *laminated fibre* or *tissue* is the most simple and abundant of animal solids. It exists in every organized being; and is an element of every solid. In the enamel of the teeth only it has not been detected. It is formed of an assemblage of thin laminæ, of delicate, whitish, extensible filaments, interlacing and leaving between each other areolæ or spaces. These filaments—although possessed, like every other living tissue, of contractility or the power of feeling an appropriate irritant and of moving responsive to such irritant—do not move perceptibly under the influence of mechanical or chemical stimuli. They are mainly composed of concrete gelatin.—The great bulk of animal solids consists of areolar tissue, arranged as membrane.

2. *Muscular fibre* or *tissue* is a substance of peculiar nature; arranged in fibres of extreme delicacy. The fibres are linear, soft, grayish or reddish, and manifestly possessed of contractility or irritability; that is, they move very perceptibly under the influence of mechanical or chemical stimuli. They are composed, essentially, of fibrin. Their histology will be described hereafter.

Muscular fibres, which are arranged in the form of membranous expansions or muscular coats, differ from proper muscles chiefly in the mechanical disposition of the fibres. The physical and chemical

[1] Elementa Physiologiæ, vol. i. lib. i. sect. i. p. 7, Lausan., 1757.

characters of both are identical. The fibres, instead of being collected into fasciculi, are in layers, and, instead of being parallel, interlace. This tissue does not exist in the zoophyte.

3. *Nervous, pulpy*, or *medullary fibre* or *tissue*, which will be referred to hereafter, is much less distributed than the preceding. It is of a pulpy consistence; is composed essentially of albumen united to a phosphuretted fatty matter; and is the organ for receiving and transmitting impressions to and from the nervous centres. Of it, brain, cerebellum, medulla spinalis, nerves and their ganglia are composed.

Professor Chaussier[1] added another primary fibre or tissue—the *albugineous*. It is white; satiny; resisting; of a gelatinous nature; and constitutes tendons and tendinous structures. He is, perhaps, the only anatomist that admits this tissue. Others properly regard it as a condensed variety of the areolar.

These various fibres or tissues, by uniting differently, constitute the first order of solids; and these again, by union, give rise to *compound solids*, from which the different organs are formed. A bone, for example, is a compound of various tissues; *osseous* in its body; *medullary* in its interior; and *cartilaginous* at its extremities.

Bichat[2] was the first anatomist who possessed clear views regarding the constituent tissues of the animal frame; and whatever merit may accrue to after anatomists and physiologists, he is entitled to the credit of having pointed out the path, and facilitated the labours of the anatomical analyst.

The term texture can only apply to solids; but inasmuch as there are in suspension in certain fluids, as the blood, chyle and lymph, solid corpuscles of determinate form and organic properties, and which are not mere products or secretions of a particular organ, or confined to a particular part, such corpuscles have been looked upon as organized constituents of the body, and therefore considered along with the solid tissues; and, accordingly, the textures and other organized constituents have been enumerated as follows:[3]

The blood, chyle and lymph.
Epidermic tissue, including epithelium, cuticle, nails, and hairs.
Pigment.
Adipose tissue.
Cellular (areolar) tissue.
Fibrous tissue.
Elastic tissue.
Cartilage and its varieties.
Bone or osseous tissue.
Muscular tissue.
Nervous tissue.
Bloodvessels.
Absorbent vessels and glands.
Serous and synovial membranes.
Mucous membranes.
Skin.
Secreting glands.

Under the idea, now entertained, that all organized tissues are essentially composed of cells having plastic or formative powers, with an intercellular substance or blastema, the tissues have been thus arranged by Schwann,[4] the great author of the cell doctrine.

[1] Table Synoptique des Solides Organiques.
[2] Anatomie Gén., Paris, 1801, tom. i.
[3] Quain and Sharpey, Human Anatomy, Amer. edit., by Dr. Leidy, i. 39, Philad., 1849.
[4] Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants. Sydenham Society's edit., by Henry Smith, p. 66, London, 1847.

1. Isolated, independent cells. To this class the cells in fluids pre-eminently belong:—lymph globules; blood corpuscles.

2. Independent cells united into continuous tissues; such as the horny tissues and the crystalline lens.

3. Cells in which only the cell walls have coalesced—cartilage, bone, and the *substantia propria* (ivory) of the teeth.

4. Fibre cells—cellular (areolar), fibrous and elastic tissue.

5. Cells in which both the cell walls and cell cavities have coalesced,—muscle, nerve and capillary vessels.

Dr. Allen Thomson[1] has proposed the following tabular view, which—he remarks—may be adopted in preference to the foregoing as combining similar theoretical considerations with a more immediate reference to the actual form of the prevailing structural elements in the different tissues. He properly adds, however, that this classification is open—as he might have said every arrangement must be—to several objections; inasmuch as it brings together, under the same head, some parts endowed with different functions; and separates some textures whose functions are closely related; and it does not point out sufficiently the usual degree of complexity of the several textures.

Some part of it, moreover, is founded on theoretical considerations not yet fully established; and the distinctions on which it rests are based on a structural analysis of various extent in the different textures. On the whole, however, it is a sufficient exponent of the existing state of belief on the subject.

I. Organized textures in which the cellular form of the constituent elements is apparent; not unfrequently also presenting granules of molecular deposition.

1. Rounded simple cells, floating loose in fluid, *Blood*, *Lymph*, *Chyle* and *Milk Corpuscles*, *&c.*

2. Simple cells massed together, either preserving their cellular form, and without other parts intervening, or altered in form and mixed with other solid elements:—*Pigment*, *Fat*, *Cuticle*, *Horny textures*, *Epithelium*, *Crystalline lens*, *Cartilage.*

3. Simple cells, or their contents, altered in form:—*Ciliated texture*, *Spermatozoa.*

4. Compound cells, separate or mixed with other textures:—*Ovum*, *Ganglionic corpuscles.*

II. Textures exhibiting a simply fibrous structure.

1. Filamentous (areolar) texture; formerly *Cellular texture.*

2. Fibrous textures:—*Tendon*, *Ligament*, *Fibrous membranes*, *Fibrous plates.*

3. Elastic fibrous texture.

III. Textures exhibiting a tubular structure.

1. Containing moving fluids:—*Bloodvessels* and *Absorbent vessels.*

2. Containing muscular substance:—*Striated* and *non-striated muscular fibre.*

3. Containing nervous matter:—*Primitive nerve tubes.*

IV. Textures exhibiting a membranous structure.

1. Principally filamentous:—*Serous* and *Synovial membranes.*

[1] Outlines of Physiology for the Use of Students, pt. i. p. 68, Edinb., 1848.

2. Filamentous and vascular:—*Mucous membranes; True skin.*
3. Membrane and cells:—*Glands.*
4. Membrane and bloodvessels, &c.:—*Lungs.*

In combining to form the different structures, the solids are arranged in various ways. Of these, the chief are in filaments or elementary fibres, tissues, organs apparatuses, and systems. A *filament* is the elementary solid. A *fibre* consists of a number of filaments united together. Occasionally this is called a *tissue*:—the term *tissue* usually, however, means a particular arrangement of fibres. An *organ* is a compound of several tissues. An *apparatus* is an assemblage of organs, concurring to the same end:—the *digestive apparatus* consists of the organs of mastication, insalivation, and deglutition, the stomach, duodenum, pancreas, liver, &c. These may be, and are, of very dissimilar character, both as regards their structure and functions; but, if they concur in the same object, they form an *apparatus*. A *system*, on the other hand, is an assemblage of organs, all of which possess the same or an analogous structure. Thus, all the muscles of the body have a common structure and function; and form, in the aggregate, the *muscular system*. All the vessels of the body, and all the nerves, for like reasons, constitute, respectively, the *vascular* and *nervous systems*.

d. *Of the Fluids of the Human Body.*

The positive quantity or proportion of the fluids in the human body does not admit of appreciation, as it must vary at different periods, and under different circumstances. The younger the animal, the greater is its preponderance. When we first see the embryo, it appears to be almost wholly fluid. As it becomes gradually developed, the proportion of solid parts increases, until the adult age; after which it becomes less and less in the progress of life. During the whole of existence, too, the quantity of fluids in the body fluctuates. At times, there is plethora or unusual fulness of bloodvessels; at others, the blood is less in quantity.

Experiments have been made for the purpose of ascertaining the relative proportion of fluids to solids. M. Richerand says, that they are in the ratio of six to one; M. Chaussier, of nine to one. The latter professor put a dead body, weighing one hundred and twenty pounds, into a heated oven, and dried it. After desiccation, it was found to be reduced to twelve pounds. It is probable, however, that some of the more solid portions were driven off by the heat employed; and hence that the estimated proportion of fluids was too high. On this account, M. Bérard[1] thinks, that instead of estimating the proportion of liquids at nine-tenths, it would be better to take the mean result of experiments by M. Chevreul, who performed the desiccation *in vacuo* and with a very moderate heat. This would give the proportion of water in the human body about 6.667 parts in the 10.000.

In the Egyptian mummies, which are completely deprived of fluid, the solids are extremely light, not weighing more than seven pounds; but as we are ignorant of the original weight of the body, we cannot

[1] Cours de Physiologie, p. 200, Paris, 1848.

arrive at any approximation. The dead bodies found in the arid sands of Arabia, as well as the dried preparations of the anatomical theatre, afford additional instances of reduction by desiccation. To a less extent, we have the same thing exhibited in the excessive diminution in weight that occurs in disease, and occasionally in those who are apparently in health. Not many years ago, an *Anatomie vivante* was exhibited in London to the gaze of the curious and scientific, whose weight was not more than eighty pounds. Yet the ordinary functions were carried on, apparently unmodified. In the year 1830, a still more wonderful phenomenon was shown. A man named Calvin Edson, forty-two years old, five feet two inches high, weighed but sixty pounds. His weight had formerly been one hundred and thirty-five pounds. For sixteen years previously, he had been gradually losing flesh, without any apparent disease, having enjoyed perfect health and appetite, and eating, drinking, and sleeping as well as any one. He was properly called the "*living skeleton.*" It was stated in the public journals[1] that Dr. Edson, a brother of Calvin, was to all appearance entirely destitute of flesh. He was, in 1847, forty-two years old; of ordinary height—five feet six inches, and yet weighed only forty-nine pounds. He retained all his faculties apparently in full vigour. We have it also, on the authority of Captain Riley,[2] that after protracted sufferings in Africa, he was reduced from two hundred and forty pounds to below ninety [?].

The fluids are variously contained; sometimes in vessels—as the blood and lymph; at others, in cavities—as the fluids secreted by the pleura, peritoneum, arachnoid coat of the brain, &c.: others are in minute areolæ—as the fluid of the areolar membrane; whilst others, again, are intimately combined with the solids. They differ likewise in density,—some existing in the state of halitus or vapour; others being very thin and aqueous—as the fluid of the serous membranes; and others of more consistence—as the secretion of the mucous membranes, animal oils, &c.

The physical and chemical properties of the fluids will engage attention when they fall individually under consideration; and we shall find that one of them at least—the blood—exhibits certain phenomena analogous to those of the living solid.

The fluids have been differently classed, according to the particular views that have, from time to time, prevailed in the schools. The ancients referred them all to four—blood, bile, phlegm or pituita, and atrabilis; each of which was conceived to abound in one of the four ages, seasons, climates, or temperaments. Blood predominated in youth, in the spring, in cold, mountainous regions, and in the sanguine or inflammatory temperament. Pituita, or phlegm, had the mastery in old age, in winter, in low and moist countries, and in the lymphatic temperament. Bile predominated in mature age, in summer, in hot climates, and in the bilious temperament; and atrabilis was the characteristic of middle age, of autumn, of equatorial climes, and of the melancholic temperament. This was their grand humoral system,

[1] Philadelphia Public Ledger, Feb. 2, 1847.

[2] Narrative of the loss of the American Brig Commerce, &c., p. 302. New York, 1817.

which has vanished before a better observation of facts, and more improved methods of physical and metaphysical investigation. The atrabilis was a creature of the imagination; the pituitous condition is unintelligible to us; and the doctrine of the influence of the humours on the ages, temperaments, &c., irrational.

Subsequently, the humours were classed according to their physical and chemical properties: they were divided, for instance, into liquids, vapours, and gases; into acid, alkaline, and neutral; into thick and thin; into aqueous, mucilaginous, gelatinous, and oily; into saline, oily, saponaceous, mucous, albuminous, and fibrinous, &c. In more modern times, endeavours have been made to arrange them according to their uses in the economy into—1, *recrementitial fluids*, or those intended to be again absorbed; 2, *excrementitial*, those that have to be expelled from the body; and 3, those which participate in both purposes, and are hence termed *excremento-recrementitial.* Blumenbach[1] divided them into crude humours, blood, and secreted humours, a division which has been partly adopted by M. Adelon:[2] and Chaussier, whose anatomical arrangements and nomenclature have rendered him justly celebrated, reckoned five classes:—1, those produced by the act of digestion—chyme and chyle; 2, the circulating fluids—lymph and blood; 3, the perspired fluids; 4, the follicular; and 5, the glandular. This arrangement has been adopted by M. Magendie,[3] and, with slight modification, is perhaps as satisfactory as any that has been proposed. All these will have to engage attention under SECRETION.

e. *Physical Properties of the Tissues.*

The tissues of the body possess the physical properties of matter in general. They are found to vary in consistence—some being hard, and others soft; as well as in colour, transparency, &c. They have, also, physical properties, analogous, indeed, to what are met with in certain inorganic substances, but generally superior in degree. These are *flexibility*, *extensibility*, and *elasticity*, which are variously combined and modified in the different forms of animal matter, but exist to a greater or less extent in every tissue. *Elasticity* is only exerted under particular circumstances: when the part, for example, is put upon the stretch or compressed, the force of elasticity restores it to its primitive state, as soon as the distending or compressing cause is withdrawn. The tissues, in which elasticity is inherent, are so disposed through the body, as to be kept in a state of distension by the mechanical circumstances of situation; but as soon as these circumstances are modified, elasticity comes into play, and produces shrinking of the substance. It is easy to see, that these circumstances, owing to the constant alteration in the relative situation of parts, must be ever varying. Elasticity is, therefore, constantly called into operation, and in many cases acts upon the tissues as a new power. The cartilages of the ribs, joints, &c., are in this manner valuable agents in particular functions.

We have other examples of the mode in which elasticity exhibits

[1] Institutiones Physiologicæ, Sect. ii., § 4. Gotting., 1798.
[2] Physiologie de l'Homme, 2de édit., i. 124. Paris, 1829.
[3] Précis Elémentaire de Physiol., 2de édit., i. 20. Paris, 1825.

itself, when the contents of hollow parts are withdrawn, and whenever muscles are divided transversely. The gaping wound, produced by a cut across a shoulder of mutton, is familiar to all Previous to the division, the force of elasticity is kept neutralized by the mechanical circumstances of situation—or by the continuity of the parts; but as soon as this continuity is disturbed,—in other words, as soon as the mechanical circumstances are altered, the force of elasticity is exerted, and produces recession of the edges. This property has been described under various names, *tone* or *tonicity*, *contractilité de tissu*, *contractilité par défaut d'extension*, &c.

The other properties, *flexibility* and *extensibility*, vary greatly according to the structure of parts. The tendons, which are composed of areolar tissue, exhibit very little extensibility; and this for wise purposes. They are the conductors of force developed by muscle, and were they to yield, it would be at the expense of the muscular efforts; but they possess great flexibility. The articular ligaments are very flexible, and somewhat more extensible. On the other hand, the fibrous or ligamentous structures, which are employed to support weights, or are antagonists to muscular action—as the *ligamentum nuchæ*, which passes from the spine to the head of the quadruped—are very extensible and elastic.

Another physical property, possessed by animal substances, is a kind of contractility, accompanied with sudden corrugation and curling. This effect, which Bichat terms *racornissement*, is produced by heat, and by chemical agents, especially the strong mineral acids. The property is exhibited by leather when thrown into the fire.

An effect, in some measure resembling this, is caused by the evaporation of the water that is united to animal substances. This constitutes what has been called the *hygrometric property* of animal membranes.[1] It is characteristic of dry, membranous structures; all of which are found to contract, more or less, by the evaporation of moisture, and to expand again by its reabsorption; hence the employment of such substances as *hygrometers*. According to M. Chevreul,[2] many of the tissues are indebted for their physical properties to the water they contain, or with which they are imbibed. When deprived of this fluid, they become unfit for the purposes for which they are destined in life, and resume them as soon as they have recovered it.

A most important property possessed by the tissues of organized bodies is *imbibition;* a property to which attention has been chiefly directed of late years. If a liquid be put in contact with any organ or tissue, in process of time the liquid will be found to have passed into the areolæ of the organ or tissue, as it would enter the cells of a sponge. The length of time occupied in this imbibition will depend upon the nature of the liquid and the kind of tissue. Some parts of the body, as the serous membranes and small vessels, act as true sponges, absorbing with great promptitude; others resist imbibition for a considerable time,—as the epidermis.

[1] Roget, art. Physiology, in Supplement to Encyclopædia Britannica; and Outlines of Physiology, with an Appendix on Phrenology. First American edition, with notes by the author of this work, p. 73, Philad., 1839.

[2] Magendie, Précis Élémentaire de Physiologie, 2de édit., 1825, i. 13.

Liquids penetrate equally from within to without; the process is then called *transudation*.

Some singular facts have been observed regarding the imbibition of fluids and gases. On filling membranous expansions, as the intestine of a chicken, with milk or some dense fluid, and immersing it in water, M. Dutrochet[1] observed, that the milk left the intestine, and the water entered it; hence he concluded, that whenever an organized cavity, containing a fluid, is immersed in another fluid less dense than that which is in the cavity, there is a tendency in the cavity to expel the denser and absorb the rarer fluid. This M. Dutrochet termed *endosmose* or "inward impulsion;" and he conceived it to be a new power, a "physico-organic or vital action." Subsequent experiments showed, that a reverse operation could take place. If the internal fluid was rarer than the external, the transmission occurred in the opposite direction. To this reverse process, he gave the name *exosmose*, or "outward impulsion." At times, the term endosmose is applied to the mutual action of two liquids when separated by a membrane;[2] at others, to the passage of the liquid, that permeates the membrane in greatest quantity.[3]

Soon after the appearance of M. Dutrochet's essay, the experiments were repeated, with some modifications, by Dr. Faust,[4] and by Dr. Togno,[5] of Philadelphia; and with like results. The fact of this imbibition and transudation was singular and impressive; and, with so enthusiastic an individual as M. Dutrochet, could not fail to give birth to numerous and novel conceptions. The energy of the action of both endosmose and exosmose is in proportion, he asserted, to the difference between the specific gravities of the two fluids; and, independently of their gravity, their chemical nature affects their power of transmission. These effects—he at once decided—must be owing to electricity. The cavities, in which the changes take place, he conceived to be like Leyden jars having their two surfaces charged with opposite electricities, the ultimate effect or direction of the current being determined by the excess of the one over the other.

In an interesting and valuable communication by Prof. J. K. Mitchell,[6] of Philadelphia, "on the penetrativeness of fluids," many of the visionary speculations of M. Dutrochet are sensibly animadverted upon. It is there shown, that he had asserted, in the teeth of some of his most striking facts, that the current was always from a less dense to a more dense fluid; and that it was from positive to negative, dependent not on an inherent power of filtration,—a power always the same when the same membrane is concerned,—but modified at pleasure by sup-

[1] Mém. pour servir à l'Histoire Anatom. et Physiol. des Animaux et des Végétaux, Paris, 1837; art. Endosmosis, in Cyclopædia of Anatomy and Physiology, part x. p. 98, June, 1837. See, also, Vierordt, art. Transudation und Endosmose, in Wagner's Handwörterbuch der Physiologie, s. 631, Braunschweig, 1848. Ludwig, Lehrbuch der Physiologie des Menschen, i. 63, Heidelb. 1852. J. Béclard, Traité elémentaire de Physiologie, p. 149, Paris, 1855.

[2] Matteucci, Lectures on the Physical Phenomena of Living Beings; translated by Pereira, p. 45, Amer. edit., Philad., 1848.

[3] Poiseuille, Comptes Rendus, xix. 944, Paris, 1844.

[4] Amer. Journal of the Med. Sciences, vii. 23, Philad., 1830.

[5] Ibid., iv. 73, Philad., 1829.

[6] Ibid., vii. 23, Philad., 1830.

posed electrical agencies. This view was subsequently abandoned by M. Dutrochet, in favour of the following principle. It is well known that porous bodies, as sugar, wood, or sponge, are capable of imbibing liquids, with which they are in contact. In such case, the liquid is not merely introduced into the pores of the solid, as it would be into an empty space; but it is forcibly absorbed, so that it will rise to a height considerably above its former level. This "osmotic force" is molecular, and is the same that we witness in the phenomena presented by the capillary tube, which affords us the simplest case of the insinuation of a liquid into a porous body. It cannot alone, however, cause the liquid to pass entirely through the body. If a capillary tube, capable of raising water to the height of six inches, be depressed, so that one inch only be above the surface, the water will rise to the top of the tube; but no part of it will escape. Even if the tube be inserted horizontally into the side of the vessel containing water, the water will only pass to the end of the tube. The same thing occurs when a liquid is placed in contact with one side of a porous membrane: it enters the pores; passes to the opposite side, and is there arrested. But if this membrane communicates with a second vessel containing a different liquid—as a saline solution, capable of mixing with the first, and affected to a different degree by capillary attraction—a new phenomenon will be presented. It will be found, that both liquids enter the pores, and pass through to the opposite side. They will not, however, be carried through with the same force: that which has the greatest power of capillary ascension, has the greatest affinity for the membrane, or will wet it more readily,—in other words, that which will rise the highest in a capillary tube,—will pass through in greater quantity, and cause an accumulation of liquid on the opposite side. The action is well shown by the simple instrument figured in the margin. It consists of a glass tube, the lower extremity of which, covered by bladder, is funnel-shaped. This M. Dutrochet termed an endosmometer. If an aqueous solution of either gum or sugar be poured into it, and the closed extremity be immersed in pure water, the water is found to pass continually into the tube by filtration through the membrane, so that the liquid will rise in the tube, and may even flow out at the upper aperture. At the same time, a portion of the mucilaginous or saccharine solution will escape from the tube through the bladder, and become mixed with the water, but the quantity will be much less than that of the water which entered.

Fig. 1.

Endosmometer.

The facts and arguments adduced by Dr. Mitchell clearly exhibit, that imbibition and transudation are dependent upon the penetrativeness of the liquid, and the penetrability of the membrane; that if two liquids, of different rates of penetrativeness, be placed on opposite sides of an animal membrane, "they will in time present the greater accumulation on the side of the less penetrant liquid, whether more or less dense; but will, finally, thoroughly, and uniformly mix on both sides; and at length, if any pressure exist on either side, yield to that, and pass to the other side."[1] In all such cases, there are both endosmose and exosmose—or double imbibition; in other words, a certain quantity of one fluid passes in, and a certain quantity of the other passes out.[2] As a general rule, imbibition takes place from the rarer to the denser medium; from pure water or dilute solutions towards those that are more concentrated. It would appear, again, that the stronger current is always from the medium which has the strongest affinity for the substance of the septum. It is well known, that in the case of a mixture of dilute alcohol covered over by a piece of bladder, the alcohol becomes concentrated, owing to the water—a denser fluid—passing more rapidly through the septum or bladder than the alcohol; but if the same mixture be tied over with elastic gum, the contrary effect will be produced—the alcohol escaping in greater quantity.[3] The general conditions of the phenomena of endosmose are:—*first*, that the two liquids shall have an affinity for the septum or interposed membrane; and, *secondly*, that they shall have an affinity for, and be miscible with each other.

A portion of the communication of Dr. Mitchell relates to an analogous subject, to which, as M. Magendie[4] has observed, little or no attention had been paid by physiologists—the *permeability of membranes by gases.* "The laminæ," M. Magendie remarks, "of which membranes are constituted, are so arranged that gases can penetrate them, as it were, without obstacle. If we take a bladder, and fill it with pure hydrogen, and afterwards leave it in contact with atmospheric air, in a very short time the hydrogen will have lost its purity, and be mixed with the atmospheric air, which has penetrated the bladder. This phenomenon is more rapid in proportion as the membrane is thinner and less dense. It presides over one of the most important acts of life—respiration; and continues after death."

Dr. Mitchell is the first individual, who directed his observation to the relative penetrativeness of different gases. This he was enabled to discriminate by the following satisfactory experiment, which we give in his own words: "Having constructed a syphon of glass, with one limb three inches long, and the other ten or twelve inches, the open end of the short leg was enlarged and formed into the shape of a funnel, over which, finally, was firmly tied a piece of thin gum elastic. By inverting this syphon, and pouring into its longer limb some clear mercury, a portion of common air was shut up in the short leg, and was in communication with the membrane. Over this end, in the mercurial trough, was placed the vessel containing the gas to be tried, and its velocity of penetration measured by the time occupied in elevating to a given degree the mercurial column in the other limb. Having thus compared the gases with common air, and subsequently by the same instrument, and in bottles with each other, I was able to arrange the following gases according to their relative facility of

[1] Amer. Journal of the Medical Sciences for November, 1833, p. 100.

[2] Magendie, Leçons sur les Phénomènes Physiques de la Vie, tom. i. p. 99, Paris, 1836–38.

[3] Henle, Allgem. Anat., or Jourdan's French translat., p. 210, Paris, 1843; and Wagner, Elements of Physiology, by Willis, p. 438, Lond., 1842.

[4] Précis Élémentaire de Physiologie, 2de édit., 1825, i. 13; and Leçons, &c., tom. i. p. 132.

transmission, beginning with the most powerful:—ammonia, sulphuretted hydrogen, cyanogen, carbonic acid, nitrous oxide, arseniuretted hydrogen, olefiant gas, hydrogen, oxygen, carbonic oxide, and nitrogen."

He found that *ammonia* transmitted in one minute as much in volume as *sulphuretted hydrogen* did in two minutes and a half; *cyanogen*, in three minutes and a quarter; *carbonic acid*, in five minutes and a half; *nitrous oxide*, in six minutes and a half; *arseniuretted hydrogen*, in twenty-seven minutes and a half; *olefiant gas*, in twenty-eight minutes; *hydrogen*, in thirty-seven minutes and a half; *oxygen*, in one hour and fifty-three minutes; and *carbonic oxide*, in two hours and forty minutes. It was found, too, that up to a pressure of sixty-three inches of mercury, equal to more than the weight of two atmospheres, the penetrative action was capable of conveying the gases—the subjects of the experiment—into the short leg through the gum elastic membrane. Hence, the degree of force exerted in the penetration is considerable.

The experiments were all repeated with animal membranes, such as dried bladder and gold-beater's skin, moistened so as to resemble the natural state. The same results, and in the same order, followed as with the gum elastic. The more fresh the membrane, the more speedy and extensive was the effect; and in living animals the transmission was very rapid.

To these experiments there will be frequent occasion to refer in the course of this work.[1]

All these different properties of animal solids are independent of the vital properties. They continue for some time after the total extinction of life in all its phenomena, and appear to be connected either with the physical arrangement of the molecules, the chemical composition of the substance in which they reside, or with peculiar properties in the body that is made to act on the tissue. They do not, indeed, seem to be affected, until the progress of decomposition has become sensible. Hence, many of them have been termed collectively, by Haller, *vis mortua*.

2. FUNCTIONS OF MAN.

Having described the intimate structure of the tissues, we pass to the consideration of the functions; the character of each of which is,—that it fulfils a special and distinct office in the economy, for which it has in general an organ or instrument, or evident apparatus of organs. Physiologists have not, however, agreed on the number of distinct offices; and hence the difference, in regard to the number and classification of the functions, that prevails amongst them. The oldest divi-

[1] See, connected with this subject, the ingenious papers by Dr. Robert E. Rogers, and Dr. Draper—the former in the American Journal of the Medical Sciences, May, 1836, p. 13; and the latter in the same Journal for August, 1836, p. 276; Nov. 1837, p. 122; and Aug. 1838, p. 302: and Abstract of Experiments upon the physical influences exerted by living, organic and inorganic membranes, upon chemical substances in solution passing through them by endosmose, by Joseph Jones, A. B., in the same Journal, for April, 1855, p. 555; and Experimental Investigations to ascertain the action of saline solutions of different densities upon living animals, and the reciprocal action, through dead animal membranes, of serum, water, and saline solutions; by the same, Ibid., Jan., 1856, p. 61.

sion is into the *vital*, *natural*, and *animal;* the *vital functions* including those of such importance as not to admit of interruption,—circulation, respiration, and innervation; the *natural functions* those that effect nutrition, digestion, absorption, and secretion; and the *animal* those possessed exclusively by animals,—sensation, locomotion, and voice. This classification, with more or less modification, prevails at the present day.

The character of this work will not admit of a detail of every classification which has been proposed; that of Bichat, however, has occupied so large a space in the public eye, that it cannot well be passed over. It is followed by M. Richerand,[1] and many modern writers. Bichat includes all the functions under two heads,—*functions of nutrition*, which concern the *life of the individual*, and *functions of reproduction*, which concern the *life of the species.* Nutrition requires, that the being shall establish relations around him to obtain the materials of which he may stand in need; and, in animals, the functions that establish such relations, are under the volition and perception of the being. Hence they are divided into two sets; those that commence or precede nutrition; have external relations; are dependent upon the will, and executed with consciousness; and those that are carried on within the body spontaneously, and without consciousness. Bichat adopted this basis; and, to the first aggregate of functions, he applied the term *animal life*, because it comprised those that characterize animality: the latter he termed *organic life*, because the functions comprised under it are common to every organized body. *Animal life* included sensation, motion, and expression; *organic life*, digestion, absorption, respiration, circulation, nutrition, secretion, &c. In animal life, Bichat recognized two series of actions, antagonistic to each other; the one proceeding from without and terminating in the brain, or passing from circumference to centre, and comprising the external senses; the other, commencing in the brain, and acting on external bodies, or proceeding from centre to circumference, and including the internal senses, locomotion, and voice. The brain, in which one series of actions terminates and the other begins, he considered the centre of animal life. In organic life, he likewise recognized two series of actions: the one, proceeding from without to within, and effecting composition; the other passing from within to without, and effecting decomposition. In the former, he included digestion; absorption; respiration, by which the blood is formed; circulation, by which the blood is conveyed to different parts; and the functions of nutrition, and calorification. In the latter, that absorption by which parts are taken up from the body; the circulation, which conducts those parts or materials to the secretory or depuratory organs; and the secretions, which separate them from the economy. In this kind of life, the circulation is common to the two movements of composition and decomposition; and, as the heart is the great organ of the circulation, he considered it the centre of organic life. Lastly, as the lungs are united with animal life in the reception of air, and with organic life as the organs of sanguification, Bichat

[1] Nouveaux Élémens de Physiologie, 13ème édit., par M. Bérard, ainé, édit. Belge, p. 42, Bruxelles, 1837; or Amer. reprint of Copland's edit. of De Lys's translation, New York, 1836.

regarded them as the bond of union between the two lives. Generation constituted the *life of the species.*

M. Brachet,[1] who gives to the sympathetic or great ganglionic nervous system a pervading influence which, it will be seen, does not properly belong to it, adopts the following classification:—

METHODICAL CLASSIFICATION OF THE FUNCTIONS.

FIRST CLASS. — Functions of ganglionic life, common to all organized bodies, and exercised under the influence of the ganglionic nervous system alone.	1. Innervation of the ganglionic nervous system. 2. Absorption. 3. Course of the lymph. 4. Circulation. 5. Nutrition. 6. Secretions.
SECOND CLASS. — Functions of cerebral life peculiar to animals, and exercised under the influence of the cerebral nervous system alone.	1. Innervation of the cerebral nervous system. 2. Sensations. 3. Intellectual functions. 4. Locomotion. 5. Voice and speech.
THIRD CLASS. — Mixed functions, requiring the influence of the two nervous systems for their complete exercise.	1. Digestion. 2. Respiration. 3. Generation. 4. Urinary excretion.
APPENDIX.	1. Relations and connections of the functions with each other. 2. Sympathies. 3. Modifications of the functions by, 1, age; 2, sex; 3, temperament; 4, habit; 5, climate, diseases, and a multitude of agents. 4. Comparative physiology.

The classification, adopted in this work, is essentially that embraced by M. Magendie;[2] and, after him, by M. Adelon,[3] who has written one of the best systems of human physiology that we possess. The FIRST CLASS, or *functions of relation or animal functions*, includes those that establish our connexion with the bodies that surround us; the *sensations*, *voluntary motions*, and *expressions*. The SECOND CLASS, or *functions of nutrition*, comprises *digestion*, *absorption*, *respiration*, *circulation*, *nutrition*, *calorification*, and *secretion;* and the THIRD CLASS, the *functions of reproduction;—generation.*

TABLE OF FUNCTIONS.

I. Functions that relate to the preservation of the individual.	I. Nutritive.	1. Digestion. 2. Absorption. 3. Respiration. 4. Circulation. 5. Nutrition. 6. Calorification. 7. Secretion.
	II. Animal or of Relation.	1. Sensation. 2. Mental and Moral Manifestations. 3. Muscular Motion. 4. Expression or Language.
II. Functions that relate to the preservation of the species.	III. Reproductive.	Generation.

In studying each of these functions, we shall first of all describe the organ or apparatus concerned in its production,—but so far only as is

[1] Physiologie Élémentaire de l'Homme, 2de édit., i. 61. Paris et Lyon, 1855.
[2] Précis, &c., i. 32. [3] Physiologie de l'Homme, 2de édit., i. 116. Paris, 1829.

necessary in a physiological point of view; and shall next detail what has been called the *mechanism* of the function, or the mode in which it is effected. In many cases, it will happen, that some external agent is concerned,—as *light* in vision; *sound* in audition; *odours* in olfaction; *tastes* in gustation. The properties of these agents will, in all instances, be detailed in a brief manner.

The difficulty of observing actions, that are carried on by the very molecules of which the organs are composed, has given rise to many hypothetical speculations, some of which are sufficiently ingenious; others too fanciful to be indulged for a moment; and, as might be expected, the number of these fantasies generally bears a direct proportion to the difficulty and obscurity of the subject. It will not be proper to pass over the most prominent of these, but they will not be dwelt upon; whilst the results of direct observation and experiment will be fully detailed; and where differences exist amongst observers, such differences will be reconciled, where practicable.

The functions, executed by different organs of the body, can be deduced by direct observation; although the minute and molecular action, by which they are accomplished in the very tissue of the organ, may not admit of detection. We see blood proceeding to the liver, and the vessels that convey it ramifying in the texture of that viscus, and becoming so minute as to escape detection even when the eye is aided by a powerful microscope. We find, again, other canals in the organ becoming perceptible, gradually augmenting in size, and ultimately terminating in a larger duct, which opens into the small intestine. If we examine each of these orders of vessels in its most minute appreciable ramifications, we discover, in the one, always blood; and, in the other, always a very different fluid—bile. We are hence led to the conclusion, that in the intimate tissue of the liver, and in some part communicating directly or indirectly with both these orders of vessels, bile is separated from the blood; or that the liver is the organ of the biliary secretion. On the other hand, functions exist, which cannot be so demonstratively referred to a special organ. We have every *reason* for believing that the brain is the exclusive organ of the mental and moral manifestations; but, as few opportunities occur for seeing it in action; and as the operation is too molecular to admit of direct observation when we do see it, we are compelled to connect the organ and function by a process of reasoning only; yet, we shall find, that the results at which we arrive in this manner are often by no means the least satisfactory.

The forces which preside over the various functions are either *general*—that is, physical or chemical; or *special*—that is, organic or vital. Some of the organs afford us examples of purely physical instruments. We have in the eye, an eye-glass of admirable construction; in the organ of voice, an instrument of music; in the ear, one of acoustics: the circulation is carried on through an ingenious hydraulic apparatus: and station and progression involve various laws of mechanics. In many of the functions, again, we have examples of chemical agency, whilst all in which innervation is concerned are incapable of being explained on any physical or chemical principle; and we are constrained to esteem them *vital*.

BOOK I.

NUTRITIVE FUNCTIONS.

The human body, from the moment of its formation to the cessation of existence, is undergoing constant decay and renovation—decomposition and composition:—so that at no two periods can it be said to have exactly the same constituents. The class of functions about to engage attention embraces those that are concerned in effecting such changes. They are seven in number;—*digestion*, by which the food, received into the stomach, undergoes, in that organ and in the intestines, such conversion as fits it for the separation of its nutritious and excrementitious portions; *absorption*, by which this nutritious portion, as well as other matters, is conveyed into the mass of blood;[1] *respiration*, by which the products of absorption and venous blood are converted into arterial blood; *circulation*, by which the vital fluid is distributed to every part of the system; *nutrition*, by which the intimate changes of composition and decomposition are accomplished; *calorification*, by which the system is enabled to resist the effects of greatly elevated or depressed atmospheric temperature, and to exist in the burning regions within the tropics, or amidst the arctic snows; and *secretion*, by which various fluids and solids are separated from the blood;—some to serve useful purposes in the animal economy; others to be rejected from the body.

CHAPTER I.

OF DIGESTION.

The food, necessary for animal nutrition, is rarely found in such a condition as to be adapted for absorption. It has, therefore, to be subjected to various actions in the digestive organs; the object of which is to enable the nutritive matter to be separated from it. These actions constitute the function of digestion; in the investigation of which we shall commence with a brief description of the organs concerned in it. These are numerous, and of a somewhat complicated nature.

1. ANATOMY OF THE DIGESTIVE ORGANS.

The human digestive organs consist of a long canal, varying considerably in its dimensions in different parts, and communicating ex-

[1] M. Robin, under Digestion, appears to include both these acts. "La *digestion* est cette fonction qui introduit par *endosmose* les matériaux, et satisfait à l'acte chimique de *composition* ou *assimilation* nutritive." Béraud, Manuel de Physiologie, p. 54, Paris, 1853.

ternally by two outlets,--the *mouth* and *anus*. It is usually divided into four chief portions—the *mouth*, *pharynx*, *œsophagus*, *stomach*, and *intestines*. These we shall describe in succession.

1. The *mouth* is the first cavity of the digestive tube, and that into which the food is immediately received, and subjected to the action of the organs of mastication and insalivation. Above and below, it is circumscribed by the jaws, and laterally by the cheeks;—anteriorly by the lips and their aperture, constituting the mouth proper; and, posteriorly, it communicates with the next portion of the tube,—the pharynx. It is invested by a mucous exhalant membrane, which is largely supplied with follicles; and into it the ducts from the different salivary glands pour their secretion.

Fig. 2.

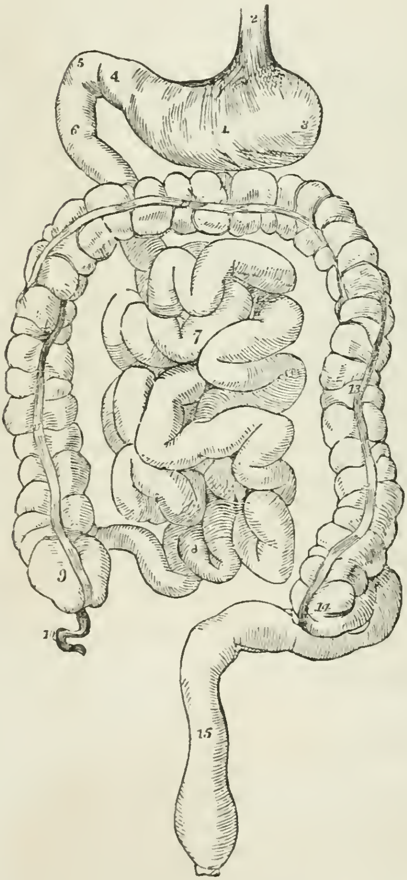


Diagram of the Stomach and Intestines to show their course.

1. Stomach. 2. Œsophagus. 3. Left, and 4. Right end of stomach. 5, 6. Duodenum. 7. Convolutions of jejuuum. 8. Those of ileum. 9. Cæcum. 10. Vermiform appendix. 11. Ascending; 12. Transverse; and 13. Descending colon. 14. Commencement of sigmoid flexure. 15. Rectum.

In all animals furnished with distinct digestive organs, means exist for comminuting the food, and enabling the stomach to act with greater facility upon it. These consist, for the most part, as in man, of the jaws, the teeth fixed into the jaws, and muscles by which the jaws are moved.

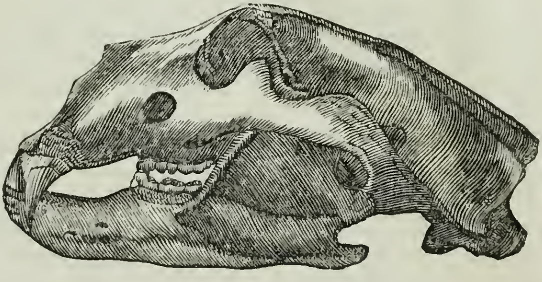
The *jaws* chiefly determine the shape and dimensions of the mouth; the *upper* forming an essential part of the face, and moving only with the head; the *lower*, on the contrary, possessing great mobility. Each of the jaws has a prominent edge, forming a semicircle, in which the teeth are implanted. This edge is called the *alveolar arch*.

The *teeth* are small organs, of a density superior to bone; and covered externally by a hard substance called *enamel*. By many, they have been regarded as bone; but they differ from it in many essential respects, although they resemble it in hardness and chemical composition. At another opportunity we shall inquire into their origin, structure, and developement. We may merely remark, at present, that by many they are looked upon as analogous to the corneous substances, which develope themselves in the tissue of the skin. De Blainville assimilates them to the hair; and believes, that they are primarily developed in the substance of the membrane lining the mouth; and that their enclosure in the substance of the alveolar arches of the jaws occurs subsequently.

The number of the teeth is sixteen in each jaw. These are divided into classes, according to their shape and use. There are, in each jaw, four *incisores;* two *cuspidati* or *canine* teeth; four *bicuspidati;* and six *molares* or *grinders*. Each tooth has three parts:—the *crown*, *neck*, and *fang* or *root;*—the first being the part above the gum; the second that embraced by the gum; and the third, that contained in the *alveolus* or socket. The crown varies in the different classes. In the incisors, it is wedge-shaped; in the canine, conical; and in the molar, cubical. In all, it is of extreme hardness, but in time wears away by the constant friction to which it is exposed. The incisor and canine teeth have only one root; the molares of the lower jaw, two; and the upper, three. In all cases, they are of a conical shape, the base of the cone corresponding to the corona, and the apex to the bottom of the alveolus. The alveolar margin of the jaws is covered by a thick, fibrous, resisting substance, called *gum*. It surrounds accurately the inferior part of the crown of the tooth, adheres to it strongly, and thus adds to the solidity of the junction of the teeth with the jaws. It is capable of sustaining considerable pressure without inconvenience.—But we shall have to return to the subject of the teeth hereafter.

The articulation of the lower jaw is of such a nature as to admit of depression and elevation; of horizontal motion forwards, backwards, and laterally; and of a semi-rotation upon one of its condyles. The muscles that move it may be thrown into two classes:—*elevators* and *depressors*. These, by a combination of their contraction, can produce every intermediate movement between elevation and depression. The raisers or levator muscles of the jaw extend from the cranium and upper jaw to the lower. They are four in number on each side,—the *temporal* and *masseter*, which are entirely concerned in the function; the *external pterygoid*, which, whilst it raises the jaw, carries it at the same time forward, and to one side; and the *internal pterygoid*, which, according as it unites its action with the temporal or with the external pterygoid, is an elevator of the jaw or a lateral motor. The depressors may be divided into immediate and mediate, according as they are, or are not, attached to the lower jaw itself. There are only three of the former class: 1, the *digastricus*, the anterior fasciculus of which, or that which passes from the os hyoides to the lower jaw, depresses the latter; 2, the *genio-hyoideus;* and 3, the *mylo-hyoideus*, all of which concur in the formation of the floor of the mouth. The indirect or mediate depressors are all

Fig. 3.

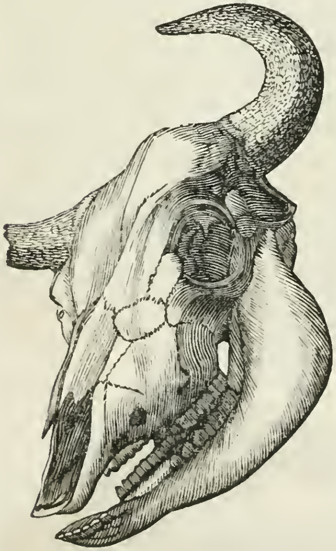


Skull of the Polar Bear.

those, that are situate between the trunk and the lower jaw, without being directly attached to the latter;—as the *thyro-hyoideus*, the *sterno-thyroideus*, and the *omo-hyoideus;* the names of which indicate their origin and insertion. These, in the aggregate, form a muscular chain, which, when it makes the trunk its fixed point, depresses the lower jaw. The arrangement of the elevators and depressors is such, that the former predominate over the latter; and hence during sleep the jaws continue applied to each other, and the mouth is consequently closed.

The human organs of mastication hold an intermediate place between those of the carnivorous and herbivorous animal. In the carnivorous animal, which has to seize hold of, and retain its prey between its teeth, the jaws have considerable strength; and the movement of elevation is all that is practicable; or, at least, that can be effected to any extent. This is dependent upon organization. The condyle is broader from side to side, which prevents motion in that direction: the glenoid cavity is very deep, so that the head of the jaw-bone cannot pass out of it; and it is, moreover, fixed in its place by two eminences before and behind. The muscular apparatus is also so arranged as to admit of energetic action on the part of the muscles that raise the jaw; but of scarcely any in a horizontal direction. The deep impressions in the regions of the temporal and masseter muscles indicate the large size of these muscles in the purely carnivorous animal; whilst the pterygoid muscles are extremely small. The teeth, too, are characteristic; the molares being comparatively small, at the same time that they are much more pointed. On the other hand, the cuspidati are remarkably large, and the incisors, in general, acuminated.

Fig. 4.



Skull of the Cow.

The herbivorous animal has an arrangement the reverse of this. The condyle or head of the lower jaw is rounded; and can, therefore, be moved in all directions; and as easily horizontally as up and down. The glenoid cavity is shallow, and yields the same facilities. The articulation, which is very close in the carnivorous animal, is here quite loose. The levator muscles are much more feeble; the temporal fossa is less deep; the zygomatic arch less convex; and the zygomatic fossa less extensive. On the other hand, the pterygoid fossa is ample and the muscles of the same name are largely developed. The molares are large and broad; and their magnitude is so great as to require, that the jaw should be much elongated in order to make room for them.

The joint of the lower jaw has, in man, solidity enough for the jaws to exert considerable pressure with impunity, and laxity enough that the lower jaw may execute horizontal movements. The action of the levator muscles is the most extensive; but the lateral or grinding motion is practicable to the necessary extent; and the muscles of both kinds have a medium degree of developement. The teeth, likewise, partake of the characteristics of those of the carnivorous and herbivorous animals;—twelve—the canine teeth and lesser molares—corresponding to those of the carnivorous; and twenty—the incisors and larger molares—to those of the herbivorous.

The tongue must be regarded as an organ of mastication. It rests horizontally on the floor of the mouth; is free above, anteriorly; and, to a certain extent, beneath and at the sides. Behind, it is united to the epiglottis by three folds of the mucous membrane of the mouth; and is supported at its base by the os hyoides, with which it participates in its movements. The tongue, as the organ of taste and articulation, is described elsewhere. We have only, therefore, to describe the os hyoides and its attachment to that bone. The hyoid bone has, as its name imports, the shape of the Greek letter υ, the convex part being before. It is situate between the tongue and larynx: and is divided into *body* or *central part;* and into branches, one extremity of which is united to the body by an intermediate cartilage, that admits of slight motion; whilst the other is free, and is called *greater cornu.* Above the point, at which the branch is articulated with the body, is an apophysis or process, called *lesser cornu.* The os hyoides is united to the neighbouring parts by fibrous organs, and muscles. The former are;—*above,* the *stylo-hyoid ligament,* which extends from the lesser cornu of the bone to the styloid process of the temporal bone; *below,* a fibrous membrane, called *thyro-hyoid,* passing between the body of the bone and the thyroid cartilage; and two ligaments, extending from the greater cornu of the hyoid bone to the thyroid cartilage, called *thyro-hyoid.* Of the muscles; some are above the hyoid bone, and raise it;—viz., the *genio-* and *mylo-hyoideus,* already referred to; the *stylo-hyoid,* and some fibres of the *middle constrictor of the pharynx.* Others are below, and depress it. They are the *sterno-thyro-hyoideus, omo-hyoideus* and *sterno-thyroideus.* The base of the tongue is attached to the body of the bone by a ligamentous tissue, and by the fibres of the *hyoglossus* muscle.

Among the collateral organs of mastication are those which secrete the saliva, and the various fluids which are poured out into the mouth, —constituting together what has been termed the *apparatus of insalivation.* These fluids proceed from different sources. The mucous membrane of the mouth, like other mucous membranes, exhales a serous or albuminous fluid, besides a mucous fluid secreted by the numerous follicles contained in its substance. Four glands likewise exist on each side, destined to secrete the *saliva,* which is poured into the mouth by distinct excretory ducts. They are the *parotid, submaxillary, sublingual,* and *intra-lingual* or *lingual.* The first is situate between the ear and the jaw; and its excretory duct opens into the mouth opposite the second small molaris of the upper jaw. By pressing upon this part of the cheek, the saliva can be made to issue into the mouth, in perceptibly increased quantity. The submaxillary gland is situate beneath the base of the jaw; and its excretory duct opens into the mouth, at the side of the frænum linguæ. The sublingual gland is situate under the tongue, and its excretory ducts open at the sides of that organ, and the intralingual or lingual is seated at the inferior surface of the tongue, where the mucous membrane forms a fringed fold. The saliva, as met with, is a compound of every secretion poured into the mouth; and it is this fluid which has been chiefly subjected to analysis. The secretion of the saliva, and its various properties, will be considered, however, hereafter.

Fig. 5.

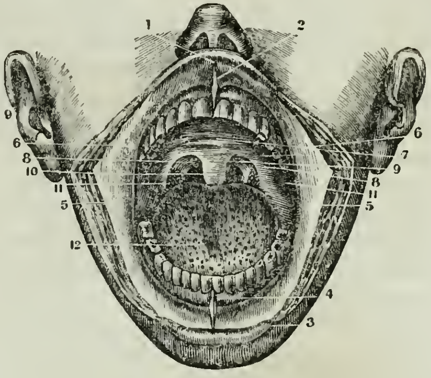
Salivary Glands in situ.

1. Parotid gland in situ, extending from the zygoma above, to the angle of the jaw below. 2. Duct of Steno. 3. Submaxillary gland. 4. Its duct. 5. Sublingual gland.

The two apertures of the mouth are the *labial* and *pharyngeal*. The former, as its name imports, is formed by the lips, which consist externally of a layer of skin; are lined internally by a mucous membrane; and, in their substance, contain numerous muscles, elsewhere described under the head of Gestures. These muscles may be separated into *constrictors* and *dilators;* the *orbicularis oris* being the only one of the first class, and the antagonist to the others, which are eight in number, on each side—*levator labii superioris alæque nasi*, *levator labii superioris proprius*, *levator anguli oris*, *zygomaticus major*, *zygomaticus minor*, *buccinator*, *triangularis*, and *quadratus menti*. To the last two muscles are added some fibres of the *platysma myoides*.

The *pharyngeal opening* is smaller than the labial, and of a quadrilateral shape. It is bounded above by the *velum palati* or *pendulous veil of the palate;* below, by the base of the tongue; and laterally, by two muscles, which form the *pillars of the fauces*. The pendulous veil is a musculo-membranous extension, constituting a kind of valve, attached to the posterior margin of the bony palate, by which all communication between the mouth and pharynx, or between the pharynx and nose can be prevented. To produce the first of these effects, it becomes vertical; to produce the latter, horizontal. At its inferior and free margin, it has a nipple-like shape, and bears the name of *uvula*. It is composed of two mucous membranes, and of muscles. One of the membranes,—that forming its anterior surface,—is a prolongation of the membrane lining the mouth, and contains numerous follicles; the other, forming its posterior surface, is an extension of the mucous membrane lining the nose, and is redder, and less provided with follicles than the other. The muscles that constitute the body of the velum palati are —the *circumflexus palati* or *spheno-salpingo-staphylinus* of Chaussier; the *levator palati* or *petro-salpingo-staphylinus;* and the *azygos uvulæ* or *palato-staphylinus.* The velum is moved by eight muscles. The two *internal pterygoids* raise it; the two *external pterygoids* stretch it transversely; the two *palato-pharyngei* or *pharyngo-staphylini*, and the two *constrictores isthmi faucium* or *glosso-staphylini* carry it downwards. The last four muscles form the pillars of the fauces;—the first two the posterior pillars; and the last two the anterior; between which are situate the *tonsil glands* or *amygdalæ*, which are composed of a congeries of mucous follicles.

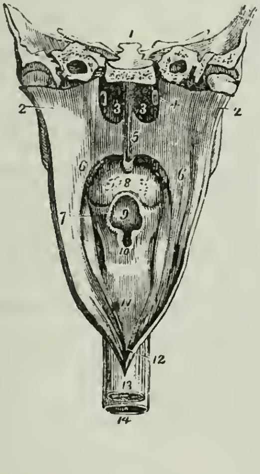
Fig. 6.



Cavity of the Mouth, as shown by dividing the Angles and turning off the Lips.

1. Upper lip, turned up. 2. Its frænum. 3. Lower lip, turned down. 4. Its frænum. 5. Internal surface of cheeks. 6. Opening of duct of Steno. 7. Roof of mouth. 8. Anterior portion of lateral half arches. 9. Posterior portion of lateral half arches. 10. Velum pendulum palati. 11. Tonsils. 12. Tongue.

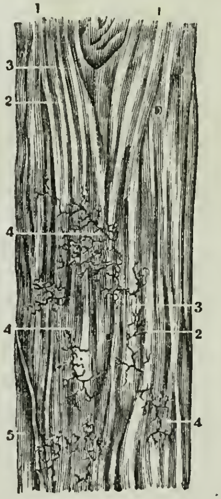
Fig. 7.



Pharynx seen from behind.

1. A section carried transversely through base of skull. 2, 2. Walls of pharynx drawn to each side. 3, 3. Posterior nares, separated by vomer. 4. Extremity of Eustachian tube of one side. 5. Soft palate. 6. Posterior pillar of soft palate. 7. Its anterior pillar; the tonsil seen situate in the niche between the two pillars. 8. Root of tongue, partly concealed by uvula. 9. Epiglottis overhanging (10) opening of glottis. 11. Posterior part of larynx. 12. Opening into œsophagus. 13. External surface of œsophagus. 14. Trachea.

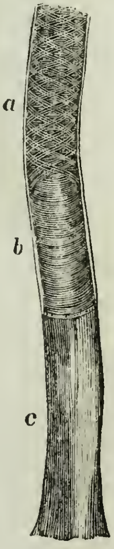
Fig. 8.



Longitudinal Section of the Œsophagus, near the Pharynx, seen on its inside.

1, 1. Superior part near pharynx. 2, 2. Longitudinal folds of its mucous membrane. 3, 3. Prominences formed by its muciparous glands. 4, 4. Capillary bloodvessels. 5. Shows the muscular coat after the mucous coat has been turned off.

Fig. 9.



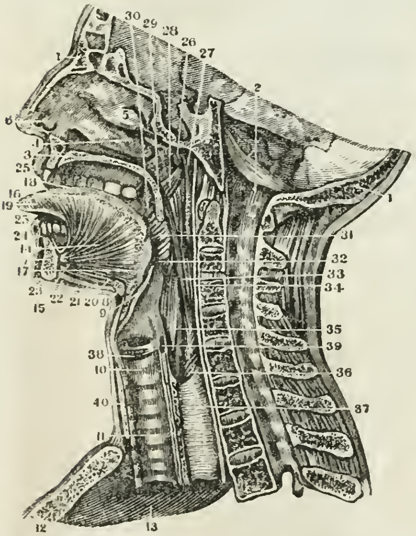
Section of the Œsophagus.

a, *b*. Internal circular fibres. *c*. External longitudinal fibres.

2. The *pharynx* and *œsophagus* constitute a muscular canal, which forms the medium of communication between the mouth and stomach, and conveys the food from the former of these cavities to the latter.

The *pharynx* has the shape of an irregular funnel,—the larger opening of the funnel looking towards the mouth and nose; the under and smaller end terminating in the œsophagus. Into its upper part, the nasal fossæ, Eustachian tubes, mouth, and larynx open. It is inservient to useful purposes in the production of voice, respiration, audition, and digestion; and extends from the basilary process of the occipital bone, to which it is attached, as far as the middle part of the neck. Its transverse dimensions are determined by the os hyoides, larynx, and pterygo-maxillary apparatus, to which it is attached. It is lined by a mucous membrane, less red than that which lines the mouth, but more so than that of the œsophagus, and the rest of the digestive tube; and it is remarkable for the developement of its veins, which form a very distinct network. Around this is the muscular layer, the circular fibres of which are often divided into three muscles—*superior*, *middle*, and *inferior constrictors.* The longitudinal fibres form part of the *stylo-pharyngei* and *palato-pharyngei* muscles. The pharynx is raised by the action of the last two muscles, as well as by all those that are situate between the lower jaw and os hyoides, which cannot raise the latter without, at the same time, raising the larynx and pharynx. These muscles are:—*mylo-hyoideus*, *genio-hyoideus*, and the anterior belly of the *digastricus*.

Fig. 10.



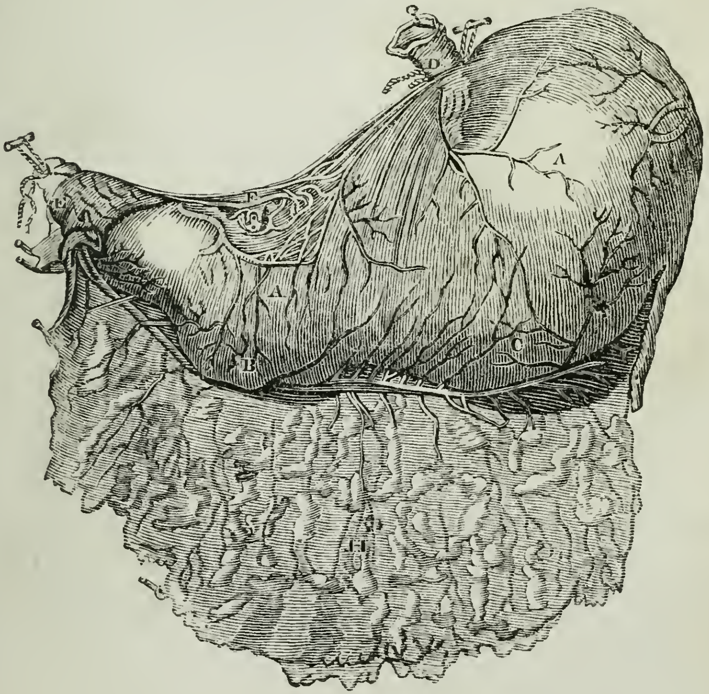
A view of the Muscles of the Tongue, Palate, Larynx and Pharynx—as well as the position of the upper portion of the Œsophagus, as shown by a vertical section of the head.

1, 1. The vertical section of the bead. 2. Points to the spinal canal. 3. Section of the hard palate. 4. Inferior spongy bone. 5. Middle spongy bone. 6. Orifice of the right nostril. 7. Section of the inferior maxilla. 8. Section of the os hyoides. 9. Section of the epiglottis. 10. Section of the cricoid cartilage. 11. The trachea, covered by its lining membrane. 12. Section of sternum. 13. Inside of the upper portion of the thorax. 14. Genio-hyoglossus muscle. 15. Its origin. 16, 17. The fan-like expansion of the fibres of this muscle. 18. Superficialis linguæ muscle. 19. Verticalis linguæ muscle. 20. Genio-hyoideus muscle. 21. Mylo-hyoideus muscle. 22. Anterior belly of digastricus. 23. Section of platysma myoides. 24. Levator menti. 25. Orbicularis oris. 26. Orifice of Eustachian tube. 27. Levator palati. 28. Internal pterygoid. 29. Section of velum pendulum palati, and azygos uvulæ muscle. 30. Stylo-pharyngeus. 31. Constrictor pharyngis superior. 32. Coustrictor pharyngis medius. 33. Insertion of stylo-pharyngeus. 34. Constrictor pharyngis inferior. 35, 36, 37. Muscular coat of œsophagus. 38. Thyreo-arytenoid muscle and ligaments, and above is the ventricle of Galen. 39. Section of arytenoid cartilage. 40. Border of sterno-hyoideus.

The *œsophagus* is a continuation of the pharynx; and extends to the stomach, where it terminates. Its shape is cylindrical, and it is connected with the surrounding parts by loose and extensible areolar tissue, which yields readily to its movements. On entering the abdomen, it passes between the pillars of the diaphragm, with which it is intimately united. The mucous membrane lining it is pale, thin, and smooth; forming longitudinal folds, well adapted for favouring the dilatation of the canal. Above, it is confounded with that of the pharynx; but below, it forms several digitations, terminated by a fringed extremity, which is free in the cavity of the stomach. It is well supplied with mucous follicles. The muscular coat is thick; its texture is denser than that of the pharynx,—and cannot, like it, be separated into distinct muscles, but consists of circular and longitudinal fibres, the former of which are more internal, and very numerous, the latter external and less numerous.

3. The *stomach* is situate in the cavity of the abdomen, and is the most dilated portion of the digestive tube. It occupies the epigastric region, and a part of the left hypochondre. Its shape has been compared, not inappropriately, to that of the bag of a bag-pipe. It is capable of holding, in the adult male, when moderately distended, about three pints. The left half of the organ has always much greater

Fig. 11.



Stomach seen Externally.

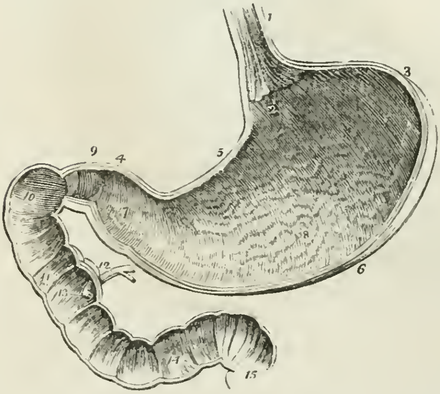
A, A. Anterior surface. B. Enlargement at lower part. D. Cardiac orifice. E. Commencement of duodenum. F and C. Coronary vessels. H. Omentum.

dimensions than the right. The former has been called the *splenic portion*, because it rests upon the spleen; the latter the *pyloric portion*, because it corresponds to the pylorus. The inferior border of the *stomach*, which is convex, is termed the *great curvature* or *arch;* the superior border, the *lesser curvature* or *arch*. The two orifices are the *œsophageal*, *cardiac* or *upper orifice*, formed by the termination of the œsophagus; and the *intestinal*, *pyloric* or *inferior orifice*, which communicates with the small intestine.

The three coats that constitute the parietes of the stomach, are arranged in a manner the most favourable for permitting variation in the size of the organ. The outermost or *peritoneal coat* consists of two laminæ, which adhere but slightly to the organ, and extend beyond it, where they form the *epiploons* or *omenta*, the extent of which is in an inverse ratio to the degree of distension of the stomach. The *omentum majus* or *gastro-colic epiploon* is the part that hangs down from the stomach in Fig. 11.

The mucous or lining membrane is of a whitish, marbled, red appearance, having a number of irregular folds, situate especially along the inferior and superior margins of the organ. These folds are evident, also, at the splenic extremity; and are more numerous and marked, the more the stomach is contracted. They are radiated towards the cardiac,—longitudinal towards the pyloric, orifice. This membrane, like every other of the kind, exhales an albuminous fluid. It contains,

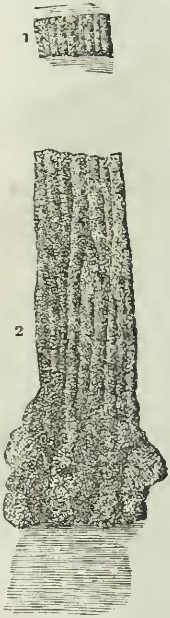
Fig. 12.



Vertical and Longitudinal Section of Stomach and Duodenum.

1. Œsophagus; upon its internal surface, the plicated arrangement of cuticular epithelium shown. 2. Cardiac orifice of stomach, around which the fringed border of cuticular epithelium is seen. 3. Great end of stomach. 4. Its lesser or pyloric end. 5. Lesser curve. 6. Greater curve. 7. Dilatation at lesser end of stomach which received from Willis the name of *antrum of pylorus*. This may be regarded as the rudiment of a second stomach. 8. Rugæ of the stomach formed by mucous membrane: their longitudinal direction is shown. 9. Pylorus. 10. Oblique portion of duodenum. 11. Descending portion. 12. Pancreatic duct, and ductus communis choledochus, close to their termination. 13. Papilla upon which ducts open. 14. Transverse portion of duodenum. 15. Commencement of jejunum. In interior of duodenum and jejunum, the valvulæ conniventes are seen.

Fig. 13.

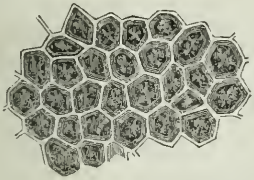


Section of a piece of Stomach not far from Pylorus.

1. Magnified about three diameters. 2. A few of the glands with their racemiform ends distended with fluid, magnified about 20 diameters.

likewise, many follicles, which are especially abundant in the pyloric portion. Several, also, exist in the vicinity of the cardiac orifice, but in the rest of the membrane they are few in number. When examined with a magnifying glass, the internal or free surface presents a peculiar honeycomb or reticulated appearance, produced by shallow polygonal

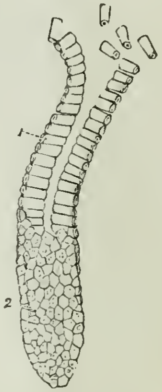
Fig. 14.



A portion of the Mucous Membrane of the Stomach magnified seventy-five times.

The alveoli measured 1-200th of an inch in length, by 1-250th in breadth; the width of the septa being 1-1000th of an inch. The smaller alveoli measured 1-250th of an inch in length, and 1-300th in breadth. The trifid or quadrifid division of a small artery is seen at the bottom of each alveolus, and in the depressions between the divisions of the artery, the apertures of the gastric follicles; two, three, or four in each depression.

Fig. 15.



Tubular Follicle of Pig's Stomach.

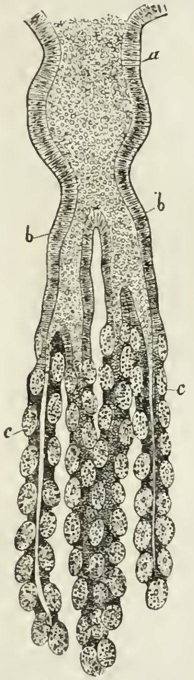
depressions or cells as represented in the marginal figures. The diameter of these cells varies from $\frac{1}{200}$th to $\frac{1}{350}$th of an inch; but, near the pylorus, it is as much as $\frac{1}{100}$th of an inch. In the bottom of the cells, minute openings are visible, which are the orifices of perpendicular glands embedded, side by side, in bundles in the substance of the mucous membrane, and composing nearly the whole structure.[1] These tubular follicles vary in length from one-fourth of a line to nearly a line. They are longer and more closely set towards the pylorus than elsewhere, their length being equal to the thickness of the mucous membrane of the stomach, which varies.

The office of the tubular follicles, it has been thought, is to secrete the gastric fluid, during digestion; for in the intervals they are at rest. They are formed by inflections of basement membrane, with cylindrical epithelium resting upon it. One of them is represented in the marginal figure, which exhibits the nucleated cells at the bottom of the follicle becoming more and more developed as they approach the free surface. These cells prepare the gastric fluid, and ultimately burst and discharge it to become mixed with the aliment in the stomach, the elaboration of the fluid in these cells seeming to be perfected only as they reach the surface, inasmuch as, according to M. Bernard,[2] the mucous membrane is not acid a little below the surface. Professors Donders and Kölliker are of opinion, that there are two great varieties of glands in the human stomach,—the *peptic gastric glands*, with *peptic stomach* or *rennet cells*, of the latter observer; and the *simple mucous glands* with cylinder epithelium, as represented in the subjoined figures from Kölliker. Thus far, however, they have only been seen in ani-

[1] Dr. Sprott Boyd, Edinb. Med. and Surg. Journal, vol. xlvi.; and E. Wilson, Lond. Med. Times and Gazette, Feb. 3, 1855.
[2] Gaz. Méd. de Paris, xix., Mars, 1844.

mals.[1] Between the different tubular follicles blood-vessels pass up and form a vascular network, in the interspaces of which the orifices of the

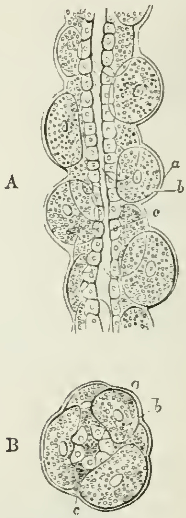
Fig. 16.



Peptic Gastric Gland.

a. Common trunk. *b, b.* Its chief branches. *c, c.* Terminal cæca with spheroidal gland-cells.

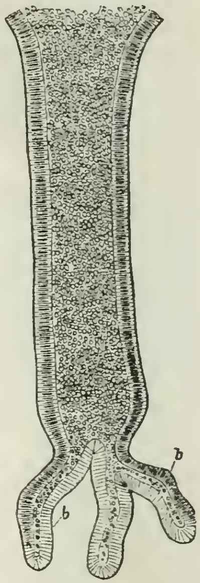
Fig. 17.



Portions of one of the cæca more highly magnified, as seen longitudinally (A), and in transverse section (B).

a. Basement membrane. *b.* Large glandular cells. *c.* Small epithelium-cells surrounding the cavity.

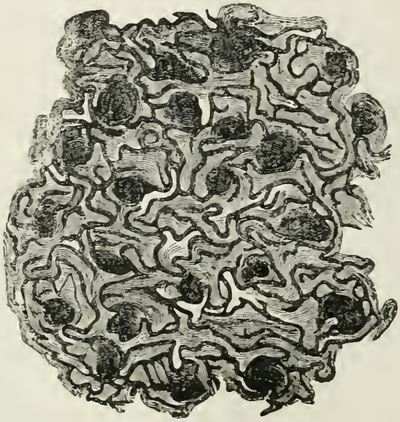
Fig. 18.



Mucous Gastric Gland, with Cylinder-Epithelium.

a. Wide trunk. *b, b.* Its cæcal appendages.

Fig. 19.



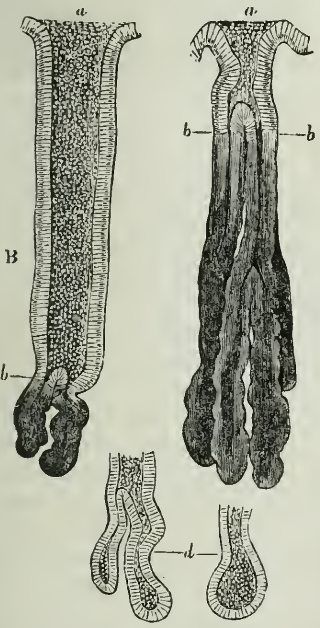
Capillary Network of the Lining Membrane of the Stomach, with the Orifices of the Gastric Follicles.

[1] Kölliker, Mikroskopische Anatomie, 2ter Band. S. 141, Leipz., 1852. Manual of Human Histology, translated by Busk and Huxley, Sydenham Society's edit., ii. 87, Lond., 1854; and American edit., by Dr. Da Costa, p. 507, Philad., 1854.

follicles are seen; and Kölliker[1] observed in the villi numerous muscular fibre cells. Brücke[2] had already pointed out a thin layer of smooth or organic muscular fibres, separated from the rest of the muscular membrane by connective tissue.

Besides these glands or follicles, small opaque, white sacculi, resembling Peyer's glands, are met with, which are filled with minute cells and granules. They are situate chiefly along the lesser curvature of the stomach beneath the lining membrane; are probably concerned

Fig. 20.

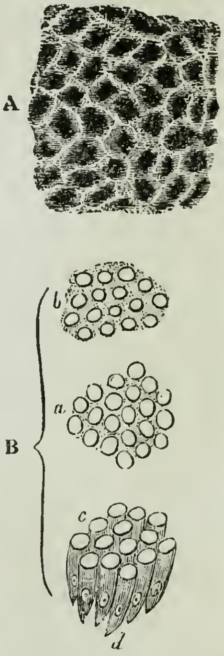


Vertical Section of a Gastric Follicle, with its Tubes.

A. In the middle region. B. In the pyloric region. *a*, *a*. Orifices of the cells on the inner surface of the stomach. *b*, *b*. Different depths at which the columnar epithelium is exchanged for glandular. *c*. Pyloric tube, or prolonged stomach cell. *d*. Pyloric tubes, terminating variously, and lined to their extremities with sub-columnar epithelium.

From the dog, after twelve hours' fasting. Magnified 200 diameters.

Fig. 21.



Mucous Membrane of the Stomach.

A. Inner surface of the stomach, showing the cells after the mucus has been washed out.—Magnified 25 diameters.

B. Columnar epithelium of the inner surface and cells of the stomach. *a*. Free ends of the epithelial particles, seen on looking down upon the membrane. *b*. Nuclei visible at a deeper level. *c*. The free ends seen obliquely. *d*. Deep or attached ends of the same. The oval nuclei are seen near the deeper ends.

From the dog.—Magnified 300 diameters.

in the separation of some secretion from the blood, and, when filled, burst, like other secreting cells, and discharge their contents into the stomach.[3]

Dr. Neill,[4] from his histological examinations of the stomach, has

[1] Op. cit.

[2] Sitzungsbericht. der Wiener Akad., vi. 214, and Canstatt's Jahresbericht, 1851, S. 119, Würzburg, 1851.

[3] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 167, Philad., 1853.

[4] Amer. Journ. of the Med. Sciences, Jan., 1851.

described the arrangement of the mucous membrane as differing essentially in the cardiac, middle and pyloric portions. In the first portion it is reticulated; in the last, villous; whilst the second is, so to speak,

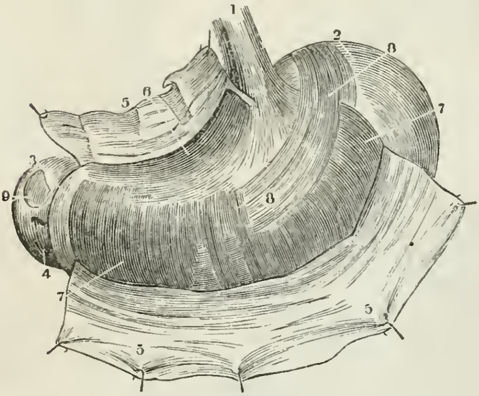
Fig. 22.

Appearance of the Lining Membrane of the Stomach, in an injected preparation.

A. From the convex surface of the rugæ. B. From the neighbourhood of the pylorus, where the orifices of the gastric follicles occupy the interspaces of the deepest portions of the vascular network.

in a transition state. In the cardiac portion the blood-vessels appear to surround the orifices of the tubes; whilst in the pyloric portion villi are distinct, but not as much so as in the small intestines. This arrangement would favour the idea, that secretion takes place more especially in the former situation, whilst absorption occurs more largely in the latter. The view is not, however, supported by Mr. Erasmus Wilson,[1] who describes the reticular arrangement as existing over the whole of the lining membrane, and it does not accord with the observations of those who consider the follicles to be especially abundant in the pyloric portion.

Fig. 23.



Front View of Stomach, distended by flatus, with Peritoneal Coat turned off.

1. Anterior face of œsophagus. 2. Cul-de-sac, or greater extremity. 3. Lesser or pyloric extremity. 4. Duodenum. 5, 5. A portion of the peritoneal coat turned back. 6. A portion of the longitudinal fibres of the muscular coat. 7. Circular fibres of the muscular coat. 8. Oblique muscular fibres, or muscle of Gavard. 9. A portion of the muscular coat of the duodenum, where its peritoneal coat has been removed.

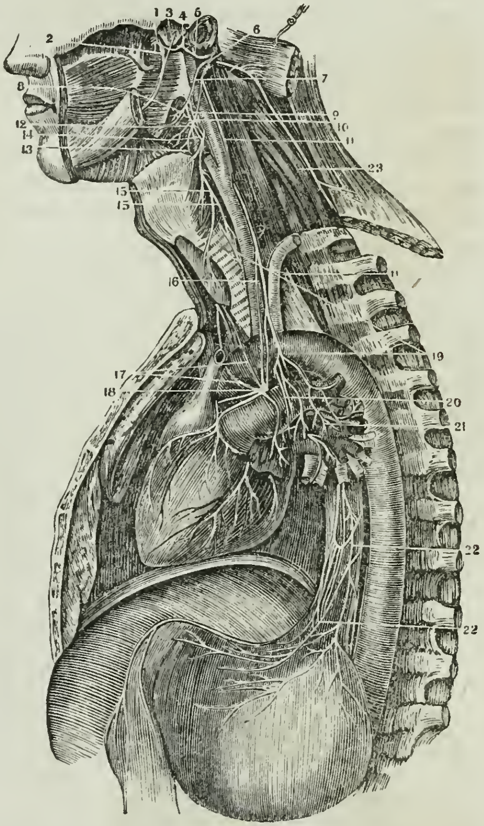
The *pylorus*, or the part at which the stomach terminates in the small intestine, is marked, externally, by a manifest narrowness. Internally, the mucous membrane forms a circular fold, which has been called *valve of the pylorus*, between the two laminæ of which, a dense, fibrous tissue exists. This has been called, by some authors, *pyloric muscle.*

The *muscular coat*, which is exterior to the mucous coat,—as in the parts of the digestive tube already described,—consists of several

[1] Op. cit.

laminæ of fibres, less distinct than those of the œsophagus; or rather more irregularly distributed. The most common opinion is, that there are three laminæ: — an external *longitudinal* series; a middle *transverse* or *circular* stratum; and an inner stratum with fibres running *obliquely*. Both circular and longitudinal fibres are separated from each other, especially in the splenic portion, — the separation augmenting or diminishing with the varying size of the stomach.

Fig. 24.



Distribution of the Glosso-Pharyngeal, Pneumogastric and Spinal Accessory Nerves, or the Eighth Pair.

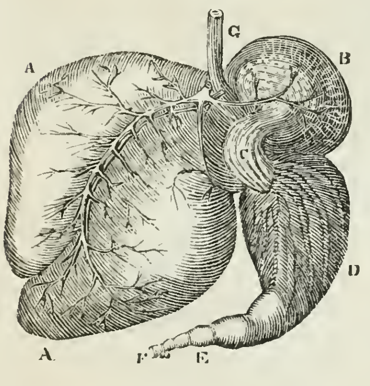
1. The inferior maxillary nerve. 2. The gustatory nerve. 3. The chorda tympani. 4. The auricular nerve. 5. Its communication with the portio dura. 6. The facial nerve coming out of the stylo-mastoid foramen. 7. The glosso-pharyngeal nerve. 8. Branches to the stylo-pharyngeus muscle. 9. The pharyngeal branch of the pneumogastric nerve descending to form the pharyngeal plexus. 10. Branches of the glosso-pharyngeal to the pharyngeal plexus. 11. The pneumogastric nerve. 12. The pharyngeal plexus. 13. The superior laryngeal branch. 14. Branches to the pharyngeal plexus. 15, 15. Communication of the superior and inferior laryngeal nerves. 16. Cardiac branches. 17. Cardiac branches from the right pneumogastric nerve. 18. The left cardiac ganglion and plexus. 19. The recurrent or inferior laryngeal nerve. 20. Branches sent from the curve of the recurrent nerve to the pulmonary plexus. 21. The anterior pulmonary plexus. 22, 22. The œsophageal plexus.

The blood-vessels and nerves of the stomach are more numerous than those of any other organ of the body. The arteries are disposed along the curvatures. On the lesser curvature are, — coronaria ventriculi, and the pyloric branch of the hepatic artery; on the great curvature, the right gastro-epiploic, which is a branch of the hepatic; and the left gastro-epiploic, — a branch of the splenic. The splenic artery, too, furnishes numerous branches to the left *cul-de-sac* behind. These are called *vasa brevia* or *gastro-splenic*. The nerves of the stomach are of two kinds. Some proceed from the great sympathetic, from the cœliac plexus, and accompany the arteries through all their ramifications. Others are furnished by the pneumogastric or eighth pair, the two nerves of which surround the cardiac orifice like a ring. The number of the nerves, and the variety of sources whence they are derived, explain the great sympathetic influence exerted upon the stomach by affections of other parts of the system. It sympathizes, indeed, with every protracted morbid change in the individual organs; and hence was termed, by Mr. Hunter, the *centre of sympathies.*

Like the teeth, the human stomach holds a medium place between that of the carnivorous and herbivorous animal. As the former makes use of aliment, which is more readily assimilated to its own nature, and more nutritious, it is not necessary that it should take food in such large quantities as the latter, or that this should remain so long in the stomach. On this account, the organ is generally of much smaller size. On the other hand, as the herbivora subsist solely upon grass, which contains but a small quantity of nutritious matter, and that not easy of assimilation, it is important that the quantity taken in should be ample; that it should remain for some time in the organ subjected to the action of its secretions; and, in the ruminant class, be returned into the mouth, to undergo fresh mastication.

In this class, the stomach is of prodigious extent. In the ox, which we may take as an example of the general structure of the organ, it consists of four separate compartments. The first stomach, A A, Fig. 25, *ventriculus* or *paunch*, is much the largest. Externally, it has two sacs or appendices; and, internally, is slightly divided into four compartments. The second stomach is the *reticulum*, *bonnet* or *honey-comb bag*, B, which appears to be a globular appendix to the paunch. It is situate to the right of the œsophagus, G, and has usually a thicker muscular coat than the paunch. Its inner surface is arranged in irregular pentagonal cells, and is covered with fine papillæ. The third stomach, C, is the smallest, and is called *omasum* or *manyplies.* It is of a globular shape, and has a thinner muscular coat than the former. It consists of numerous broad laminæ, sent off from the internal coat, running in a longitudinal direction, alternately varying in breadth, and covered with small granular papillæ. The fourth stomach, D, is the *abomasum*, *ventriculus intestinalis*, *reed*, or *caillette.* It has a pyriform shape, and is next in size to the paunch. It has large longitudinal rugæ, covered with villi. The muscular coat is still thinner than that of the former. This stomach is the only one that resembles the human organ; and, in the young of the ruminant animal, with the milk curdled in it, forms the *runnet* or *rennet.* The property of curdling milk is, however, possessed by all digestive stomachs. The inner surface of the three first stomachs is covered with cuticle; whilst that of the fourth is lined by a true mucous or secreting membrane. There is in the interior arrangement of the stomachs of the ruminant animal a singular provision by which the food can be either received into the first

Fig. 25.



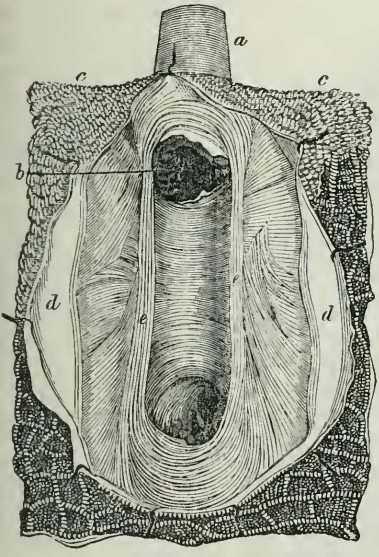
Stomach of the Ox.

A, A. Paunch. B. Reticulum. C. Omasum. D. Abomasum. E Pylorus. F. Duodenum. G. Œsophagus.

and second stomachs, or be carried on into the third, if its character be such as to be fitted at first for the action of the omasum.

From the œsophagus, in Fig. 26, a gutter or demi-canal passes into the second and third stomachs. The third leads into the fourth by a narrow opening, and the fourth terminates in the duodenum, which has a pylorus at its origin. When the animal eats solid food, it is, after slight mastication, passed into the paunch, and thence, by small portions, into the second stomach. When this has become mixed with

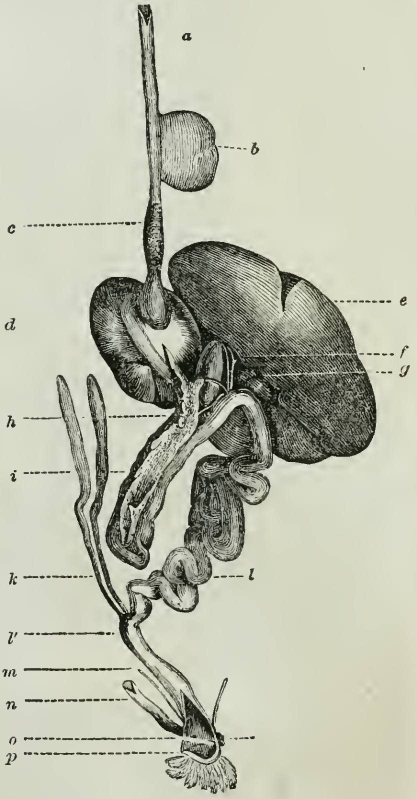
Fig. 26.



Section of part of the Stomach of the Sheep, to show the demi-canal of the œsophagus; the mucous membrane is for the most part removed, to show the arrangement of the muscular fibres.

At *a* is seen the termination of the œsophageal tube, the cut edge of whose mucous membrane is shown at *b*. The lining of the first stomach is shown at *c*, *c*; and the mucous membrane of the second stomach is seen to be raised from the subjacent fibres at *d*. At *e*, *e*, the lips of the demi-canal are seen bounding the groove, at the lower end of which is the entrance to the third stomach or manyplies.

Fig. 27.



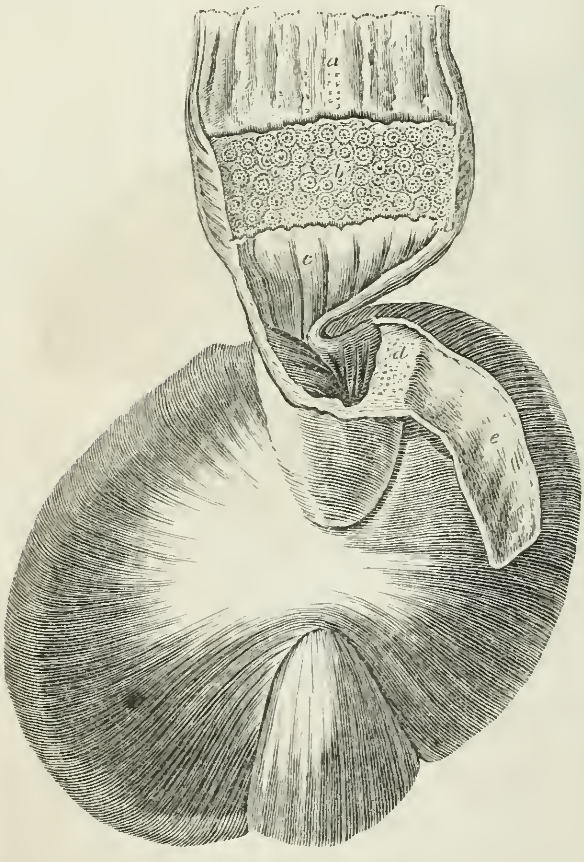
Digestive Apparatus of Common Fowl.

a. Œsophagus. *b*. Ingluvies or crop. *c*. Proventriculus. *d*. Gizzard. *e*. Liver. *f*. Gall-bladder. *g*. Pancreas. *h*. Duodenum. *i*. Small intestine. *k*. Cæca. *l*. Large intestine. *m*, *m*. Ureters. *n*. Oviduct. *o*. Cloaca.

fluid, and kept for some time at a moderately high temperature, a morsel is thrown back with velocity from the stomach into the mouth, where it is "ruminated," and then swallowed and passed on into the third stomach,—the groove or gutter being now so contracted as to form a channel for its passage through the first two. In the third and fourth stomachs, more especially the latter, true digestion takes place. When the food is of such a character as not to require rumination, it can be sent on directly into the third stomach, by the arrangement just described.

In bird tribes, we see an admirable adaptation of structure to the functions which the digestive organs have to execute. Animals of this class may be divided into the granivorous and the carnivorous. It is in the former, that we are so much impressed with the organization of this part of their economy. The grain on which they feed, although more nutritious than grass, which constitutes the aliment of the herbivorous quadruped, requires equal difficulty in being assimilated to the nature of the being it has to nourish. Added to this, it is in such a condition, that the juices of the digestive organs cannot readily act upon it. The bird having no masticatory apparatus within the mouth, the grain must of necessity be swallowed whole. But we find that lower down in the alimentary tube, a powerful masticatory apparatus exists, which has frequently been considered as a part of the digestive stomach; but really seems destined for mastication only. The following is the arrangement of their gastric apparatus.

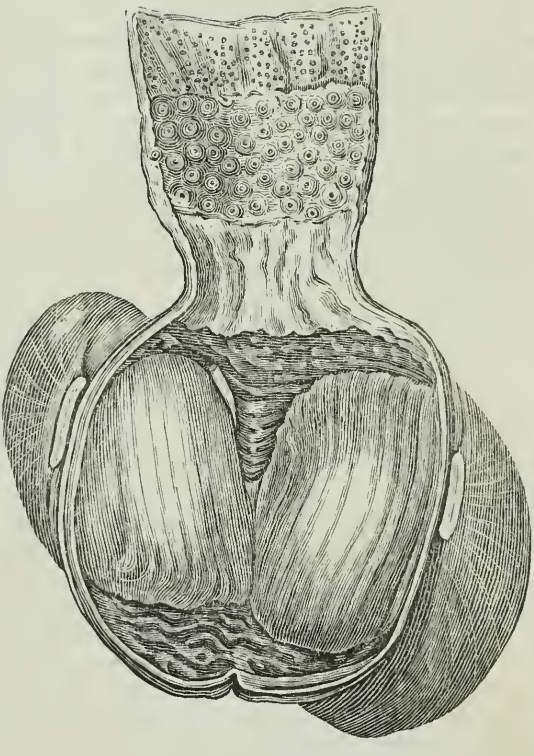
Fig. 28.



Gastric Apparatus of the Turkey.

The œsophagus terminates at the bottom of the neck in a large sac—*ingluvies*, *crop* or *craw*—which is of the same structure with the œsophagus, but thinner. On the inner side of the crop are numerous glands, with very distinct orifices in large birds, which secrete a fluid to assist in the solution of the food. To the crop succeeds another cavity, in the shape of a funnel, called *proventriculus*, *infundibulum* or *second stomach*. This is seated in the abdomen, and is generally smaller than the former. It is usually thicker than the œsophagus, partly owing to its numerous glands, which are very large and distinct in many birds. In the ostrich, they are as large as the garden-pea, and have very manifest orifices. The infundibulum terminates in the *ventriculus callosus*, *gizzard* or *third stomach*—the most curious of all the parts of the apparatus. Figs. 28 and 29 afford an external and internal view of the gastric apparatus of the turkey; *a*, representing the œsophagus immediately below the crop, covered with cuticle; *b*, the openings of the gastric glands in the second stomach, placed on a surface, that has no cuticular covering; *c*, horny ridges, between the gastric glands and the lining of the gizzard; *d*, a minutely granulated surface between the cavity of the gizzard and duodenum; and *e*, the inner surface of the duodenum. Fig. 28 accurately represents the mode in which the second stomach terminates in the gizzard, and the latter in the duodenum; the gizzard forming a kind of pouch depending from the alimentary canal. The gizzard is usually of a globular figure, flattened at the sides, and is considered to consist of four muscles, remarkable for their great thickness and strength;—a large hemispherical pair at the sides, and a small pair situate at the extremities of the stomach. The gizzard is covered externally by a beautiful tendinous expansion; and is lined by a thick, strong, callous coat, which appears to be epidermous in its character. On this are irregularities, adapted to each other on the opposite surfaces. The cavity of the organ is remarkably small, when compared with its outward magnitude, and its two orifices, represented in Fig. 28, are very near each other. In the pouch formed by the small muscles at the lower part of the gizzard, numerous pebbles are contained, which seem to be indispensable to the digestion of certain tribes, by acting as substitutes for teeth. In the gizzard of the turkey, two hundred have been found; in that of the goose, one thousand.[1]

Fig. 29.



Interior of the Gastric Apparatus of the Turkey.

[1] J. Hunter, Observations on certain parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 119, Philad., 1840; and Roget, Animal and Vegetable Physiology, Amer. edit., ii. 126. Philad., 1836.

The prodigious power with which the *digastric muscle*—as it has been termed—acts, and the callous nature of the cuticle, are strikingly manifested by certain experiments, instituted by the *Academia del Cimento*,[1] and by Redi, Réaumur,[2] and Spallanzani.[3] They compelled geese and other birds to swallow needles and lancets, and in a few hours afterwards killed and examined them. The needles and lancets were uniformly found broken off and blunted, without the slightest injury having been sustained by the stomach.

In the carnivorous bird, the food being readily assimilated, in consequence of its analogy to the substance of the animal, the gastric apparatus is as simple as in the carnivorous mammalia. The œsophagus is of great size for receiving the large substances swallowed by these animals, and for enabling the feathers and other matters, that cannot easily be digested, to be rejected by the mouth. The stomach is a mere musculo-membranous sac; but the secretion from it is of a potent character, so as to enable the animal to dispense with mastication, and yet to admit of the stomach and intestines being disposed within a small compass, so as to give them the necessary lightness to fit them for flight.

We can thus, from organization, generally form an idea of the kind of food for which an animal is naturally destined: whether, for example, it is naturally granivorous or carnivorous. There are some striking facts, however, that exhibit the signal changes exerted, even on organization, by restricting an animal to diet of a different character from that to which it has been accustomed; or to one which is foreign to its nature. In birds of prey, the digastric muscle has the bellies, which compose it, so weak, that, according to Sir Everard Home,[4] nothing but an accurate examination can determine its existence. But if a bird of this kind, from want of animal food, be compelled to live upon grain, the bellies of the muscle become so large, that they would not be recognized as belonging to the stomach of a bird of prey. Mr. Hunter kept a sea-gull for a year upon grain, when he found the strength of the muscle much augmented. This wondrous adaptation of structure to the kind of food which the animal is capable of obtaining, is elucidated by the South American and African ostriches. The former is the native of a more productive soil than the latter; and, accordingly, the gastric glands are less complex and numerous; and the triturating organ is less developed.[5]

4. The *intestines* are the lowest portion of the digestive apparatus; constituting a musculo-membranous canal, which extends from the pyloric orifice of the stomach to the anus. The human intestines are six or eight times longer than the body; and hence the number of convolutions in the abdominal cavity. They are attached to the vertebral column by folds of peritoneum called *mesentery;* and according to the length of these folds or duplicatures the intestine is bound down, or

[1] Exper. fatte nell' Acad. del Cimento, 2da ediz., Firenz., 1691.

[2] Mémoir de l'Acad. pour 1752, p. 266 and p. 461.

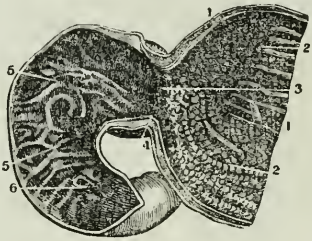
[3] Dissertations relative to the Natural History of Animals and Vegetables, English translation, i. 16, London, 1789.

[4] Lectures on Comparative Anatomy, i. 271, Lond., 1814.

[5] Ibid., i. 293. See, on all this subject, Carpenter's Principles of Comparative Physiology, Amer. edit., pp. 190 and 200, Philad., 1854.

floats in the abdominal cavity. Their structure is nearly alike throughout: a *mucous* membrane lines them: immediately without this is a *muscular* coat; and, externally, a *serous* coat, formed by a prolongation of the peritoneum. The mucous membrane is soft and velvety, and is the seat of a similar secretion to that of other membranes of the same class. The muscular coat is composed of two planes of fibres, so united that they cannot be separated,—the innermost consisting of circular, and the outermost of longitudinal fibres, the arrangement of which differs in the small and large intestines. The serous or peritoneal coat receives the intestine between two of its laminæ, which, in their passage to it, form the *mesentery*. The serous coat only comes in direct contact with the intestine at the sides and forepart. Behind, or on the mesenteric side, is a vacant space, by which the vessels and nerves reach and leave the intestine. These form their first network between the serous and muscular coats; their second, between the muscular and mucous.

Fig. 30.



Portion of the Stomach and Duodenum laid open to show their interior.

1, 1. Right or pyloric extremity of stomach. 2, 2. Folds and mucous follicles of mucous coat of stomach. 3. Points into the pylorus. 4. Thickness of the pylorus. 5, 5. Rugæ of the internal coat of the duodenum. 6. Opening of the ductus communis choledochus into the duodenum.

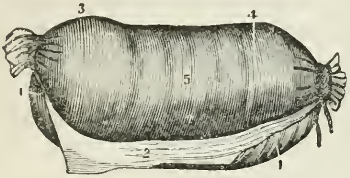
Between the upper four fifths of the intestinal canal, and the lower fifth, there is a well-marked distinction; not only as regards structure and magnitude, but function. This has given occasion to a division of the canal into *small* and *large intestine;* and these, again, have been subdivided in the various modes that will fall under consideration. As the *small intestine* forms so large a portion of the intestinal canal, its convolutions occupy considerable space in the abdominal cavity,—in the middle, umbilical, and hypogastric regions,—and terminate—in the right iliac region—in the large intestine. Its calibre differs in different parts; but it may be regarded on the average as about one inch. It is usually divided, arbitrarily, into three parts;—*duodenum*, *jejunum*, and *ileum*. The *duodenum* is so called, in consequence of its length having been estimated at about twelve fingers' breadth. It is larger than the rest of the small intestine; and has received, also, the name of *second stomach*, and of *ventriculus succenturiatus*. It is more firmly fixed to the body than the other intestines; and does not, like them, float loosely in the abdomen. In its course to its termination in the jejunum, it describes a kind of Italic *c*, the concavity of which looks to the left. From this shape it has been separated into three portions;—the first situate horizontally beneath the liver: the

Fig. 31.

Longitudinal Section of the Upper Part of the Jejunum extended under water.

second descending vertically in front of the right kidney; and the third in the transverse mesocolon. Its mucous membrane presents a number of circular folds or rugæ, very near each other, which have been called *valvulæ conniventes*. (Figs. 30 and 31.) By some anatomists, however,

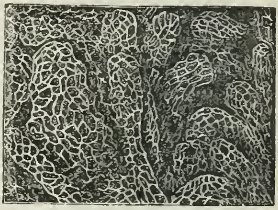
Fig. 32.



Muscular Coat of the Ileum.

1, 1. Peritoneal coat. 2. A portion of this coat turned off and showing a portion of the longitudinal fibres of the muscular coat adherent to it. 3, 4, 5. Circular muscular fibres in different parts of the intestine.

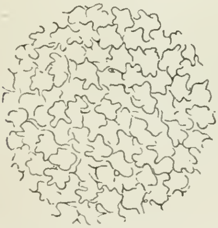
Fig. 33.



Distribution of Capillaries in the Villi of the Intestine.

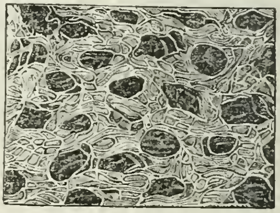
this name is not given to the irregular rugæ of its mucous coat; but to those of the lining membrane of the jejunum. The valvulæ are not simple rugæ, passively formed by the contraction of the muscular coat. They are dependent upon the original formation of the mucous mem-

Fig. 34.



Arrangement of the capillaries on the mucous membrane of the large intestine in the human subject.—Magnified 50 diameters.

Fig. 35.



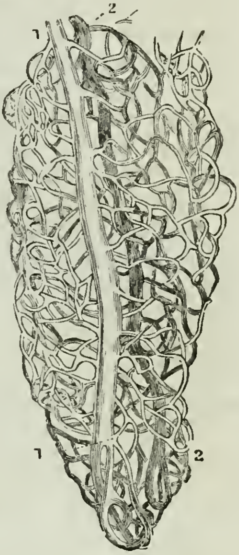
Distribution of Capillaries around Follicles of Mucous Membrane.

brane; and are not effaced, whatever may be the distension of the intestine. On and between these duplicatures, the different exhalant and absorbent vessels are situate, forming, in part, the *villi* of the intestine, which are from a quarter of a line to a line and two-thirds in length.[1] These villi give to the membrane a velvety appearance, and are not simply composed of exhalants and absorbents, but of nerves; all of which are distributed on an areolar and perhaps erectile tissue. In its healthy state, when successfully injected, the membrane appears to consist almost entirely of a cribriform intertexture of veins. It was formerly believed, that the villi are not supplied with bloodvessels. In each villus, however, there is a minute vascular plexus, the larger branches of which, when distended with blood, may be seen even by the naked eye. Marginal illustration, Fig. 36, exhibits the vessels of one of the intestinal villi of the hare, from Wagner, after an extremely

[1] J. Müller, Elements of Physiology, by Baly, 2d edit., p. 285, Lond., 1840.

beautiful dry preparation by Döllinger, magnified about 45 diameters. The most obvious use of these villi is to increase the surface from which the secretion is prepared, and from which absorption is effected. Within the membrane are numerous follicles, which, with the exhalants, secrete a mucous fluid, called by Haller *succus intestinalis*. Their entire number in the whole alimentary canal is estimated by Dr. Horner to be 46,900,000.[1] At about four or five fingers' breadth from the pylorus, the duodenum is perforated by the termination of the biliary and pancreatic ducts, which pour bile and pancreatic fluids into it. Generally, these ducts enter the intestine by one opening; at times, they are distinct, and lie alongside each other. The structure of the duodenum is the same as that of the whole of the intestinal canal. The muscular coat is, however, thicker, and the peritoneal coat only covers its first portion, passes before the second, and is totally wanting in the third, which we have described as included in the transverse mesocolon.

Fig. 36.

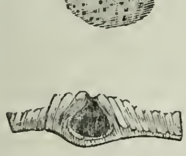


Bloodvessels of Villi of the Hare.

1, 1. Veins filled with white injection. 2, 2. Arteries filled with red. A beautiful rete of capillaries between the two.

The other two portions of the small intestine are of considerable length; the *jejunum* commencing at the duodenum, and the *ileum* terminating, in the right iliac fossa, in the first of the great intestines—the cæcum. They occupy the middle and almost the whole of the abdomen, being surrounded by the great intestine (Fig. 2). The jejunum is so called from being generally found empty; and the ileum from its numerous windings. The line of demarcation, however, between the duodenum and jejunum, as well as between the latter and the ileum, is not fixed: it is an arbitrary division.

Fig. 37.



One of the Glandulæ Majores Simplices of the Large Intestine, as seen from above, and also in a Section.

Fig. 38.

Vertical Section of the Mucous Membrane of the Duodenum in the Horse, slightly magnified.

v. Villi. *b*, *c*. Mucous membrane and submucous tissue. *g*. Brunner's glands cut vertically, and a little spread out, showing their lobulated structure.

The jejunum has, internally, the greatest number of valvulæ conniventes and villi. The ileum is the lowest portion. It is of a paler colour, and

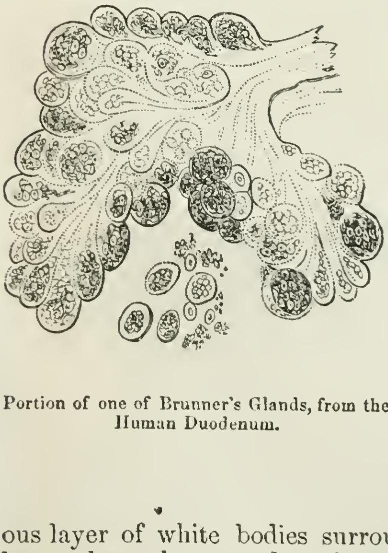
[1] Special Anatomy and Histology, 8th edit., ii. 51, Philad., 1851.

has fewer valvulæ conniventes. The jejunum is situate at the upper part of the umbilical region; the ileum at the lower part, extending as far as the hypogastric and iliac regions. The mucous membrane of the jejunum and ileum resembles, in all essential respects, that of the duodenum; the valvulæ conniventes are, however, more numerous in the jejunum than in the duodenum; and, in the course of the ileum, they gradually disappear, and are replaced by simple longitudinal rugæ. The villi, too, which are chiefly destined for chylous absorption, abound in the jejunum, but gradually disappear in the ileum. The mucous membrane of both is largely supplied with follicles, commonly called glands of Brunner and Lieberkühn, which are concerned in secreting the *succus entericus*, *succus intestinalis*—a mucous fluid to which, in digestion, Haller attached great importance. M. Lelut[1] estimates the number of these glands in the small intestine at 40,000. Dr. Horner considers the follicles to be formed, in every instance, of meshes of veins; the arteries entering inconsiderably into their composition,—or in about the same proportion as they do in other erectile tissues.[2]

The tubular glands of the small intestine have long been known under the name of *follicles of Lieberkühn.* These become especially evident if the mucous membrane is inflamed, when they are filled with an opaque whitish secretion, which is absent in the healthy state.[3]

The true *glands of Brunn* or *Brunner* are chiefly in the duodenum. They are situate in the submucous tissue, where they form a continu-

Fig. 39.



Portion of one of Brunner's Glands, from the Human Duodenum.

Fig. 40.

Section of the Mucous Membrane of the Small Intestine in the Dog, showing Lieberkühn's follicles and villi.

a. Villi. *b.* Lieberkühn's follicles. c. Other coats of the intestine.

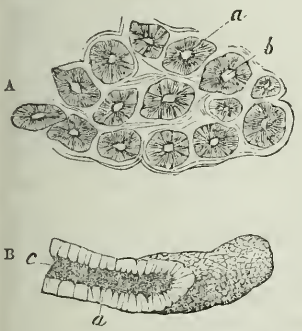
ous layer of white bodies surrounding the intestine. They are not larger than a hemp-seed; each consisting of numerous minute lobules,

[1] Gazette Médicale, Juin, 1832. [2] Op. cit., ii. 54.
[3] Boehm, cited in Brit. and For. Med. Rev., i. 521, Lond., 1836.

the ducts of which open into a common excretory duct. They are complex structures, differing from the other glands and follicles of the intestines. Nothing is positively known of the nature of their secretion.

The *glands of Peyer* form large patches on the mucous membrane, when they are called *glandulæ agminatæ* and *Peyer's patches.* Examined in a healthy mucous membrane, they have the appearance of

Fig. 41.



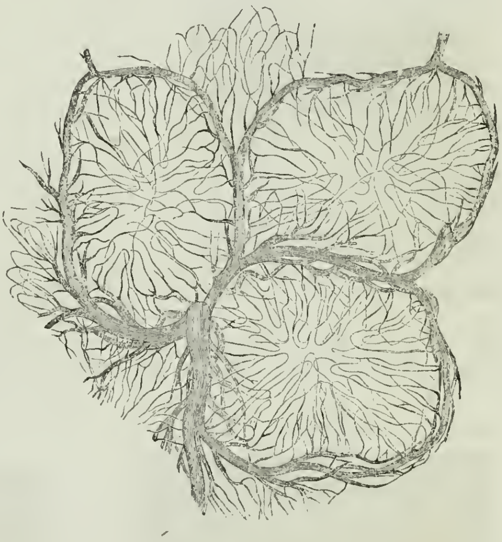
A. Transverse section of Lieberkühn's Tubes or Follicles, showing the basement-membrane and subcolumnar epithelium of their walls, with the Areolar Tissue which connects the tubes.

a. Basement-membrane and epithelium, constituting the wall of the tube. *b.* Cavity or lumen of the tube. Magnified 200 diameters.

B. A single Lieberkühn's Tube, highly magnified.

A happy accidental section in the oblique direction has served to display very distinctly the form and mode of packing of the epithelial particles, the cavity of the tube, and the mosaic pavement of its exterior. *a.* Basement-membrane. *c.* Internal surface of the wall of the tube. Magnified 200 diameters.

Fig. 42.



Horizontal Section through the middle plane of three Peyerian Glands in the Rabbit, showing the distribution of the Bloodvessels in the interior.

circular white, slightly raised spots, about a line in diameter, over which the mucous membrane is least studded with villi, and often wholly without them. On rupturing one of the white bodies a cavity is found, but it has no excretory duct. It contains a grayish-white mucous matter. There are likewise closed solitary glands in both the small and large intestines.[1] At times, however, the aggregatæ exhibit openings so distinct, as to have warranted the belief that such openings are the normal condition;[2] yet Kölliker considers it as quite certain, that the follicles of Peyer's patches are shut sacs (*gänzlich geschlossen.*)[3]

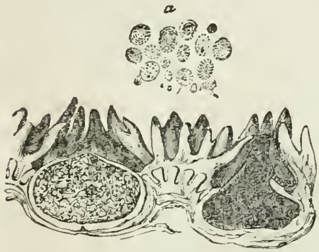
[1] Baly, Lond. Med. Gazette, Mar., 1847.

[2] Allen Thomson, in Goodsir's Annals of Anatomy and Physiology, No. 1, p. 34, Feb. 1850; and Carpenter's Principles of Human Physiology, Amer. edit., p. 153, note, Philad., 1855.

[3] Mikroskopische Anatomie 2ter Band. s. 187 and 528, Leipz., 1852; or Amer. edit. of Sydenham Society's edition of his Human Histology, by Dr. Da Costa, p. 523, Philad., 1854.

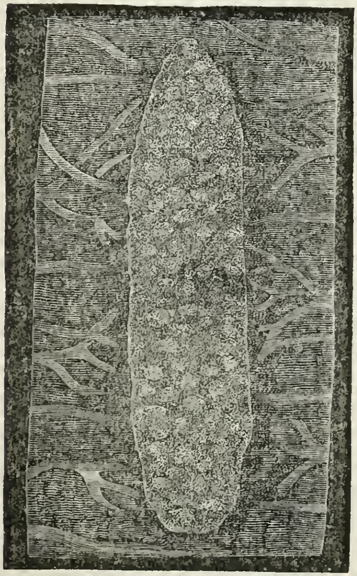
The precise use of the glands of Peyer is generally considered to be unknown. Wagner[1] has well observed, that the intimate structure of the whole of these glandular bodies requires farther study, and is almost as little known as their individual functions. It has been conceived, that they secrete a putrescent matter from the blood, which may be concerned in giving to the excrement its peculiar odour; this matter, as in other cases, being formed by cells, which burst on the free surface of the mucous membrane, and discharge their contents to be mixed with the fæces. Such has been the view, until recently, embraced by Dr. Carpenter. Professor Brücke,[2] of Vienna, adopts a different opinion—maintaining, that they are always closed in their natural condition. He regards them as appendages to the lymphatic system; as the lymphatics can be filled by injections directed from them. The contents of their areolæ or cells resemble also, in appearance and character, those of the mesenteric ganglia. This view is embraced by Professors Frei,

Fig. 43.



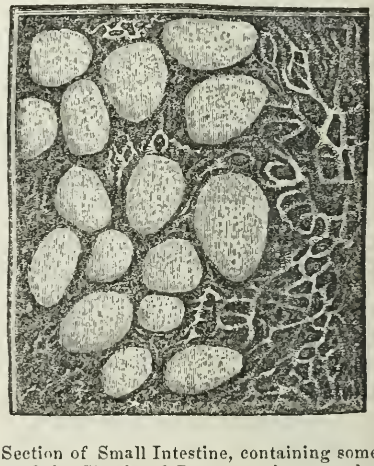
Vertical Section of two of the Peyerian Glandulæ from the Ileum of the Pig, one of them closed and full, the other open and empty, with their neighbouring villi; magnified 15 diameters. *a*. Cellular contents of the vesicle; magnified 250 diameters.

Fig. 44.



A patch of Peyer's Glands of the adult human subject, from the lowest part of the Ileum.—After Boehm.

Fig. 45.



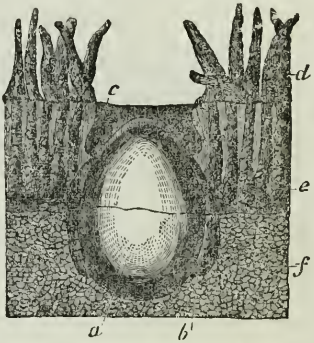
Section of Small Intestine, containing some of the Glands of Peyer, as shown under the microscope.

These glands appear to be small lenticular excavations, containing, according to Boehm, a white, milky, and rather thick fluid, with numerous round corpuscles of various sizes, but mostly smaller than blood globules. The meshes seen in the cut are the ordinary tripe-like folds of the mucous coat.

[1] Elements of Physiology, translated by R. Willis, § 137, Lond., 1842.
[2] Denkschriften der K. Akademie der Wissenschaft. Wien, 1850.

Kölliker,[1] Donders, and Gerlach,[2] as well as the opinion of Professor Brücke, that they are ganglia for the elaboration of the chyle, which passes through them by the delicate chyliferous vessels, which originate in the villi, on their way to the mesenteric ganglia; and Dr. Carpenter[3] admits, that the results appear to prove quite conclusively, that the Peyerian glandulæ are really appendages to the absorbent system, corresponding in every respect, save their situation, to the mesenteric and lymphatic glands.

Fig. 46.



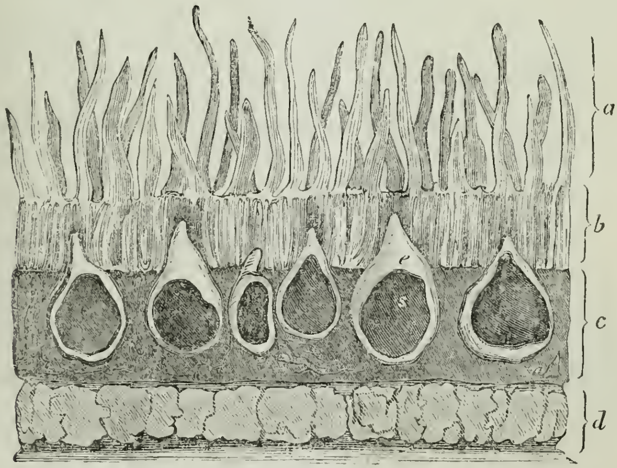
Side View of Intestinal Mucous Membrane of a Cat.

a. A Peyer's gland, imbedded in submucous tissue, *f.* *b.* A tubular follicle. *c.* Fossa in mucous membrane. *d.* Villi. *e.* Follicles of Lieberkühn.

The muscular coat of the small intestine is composed of circular and longitudinal fibres; and the outer coat is formed by the prolongation of the peritoneum, which, after having surrounded the intestines, completes the mesentery, by which the gut floats, as it were, in the abdominal cavity.

The *large intestine* terminates the intestinal canal. It is much shorter than the small, and considerably more capacious, being manifestly intended, in part, as a reservoir. It is less loose in the abdominal cavity than the portion of the tube which we have described. It commences at the right iliac fossa (Fig. 2);

Fig. 47.



Vertical Section through a patch of Peyer's Glands in the Dog.

a. Villi. *b.* Tubes of Lieberkühn with the apices of Peyer's glands. *c.* Submucous tissue with the glands of Peyer imbedded in it. *d.* Muscular and peritoneal coats. *e.* Apex of one of Peyer's glands projecting among the tubes of Lieberkühn. The glands are seen laid open by the section. Magnified about 20 diameters.

[1] Manual of Human Microscopical Anat., Amer. edit. by Da Costa, p. 516, note, and page 523, Philad., 1854.

[2] Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 527.

[3] Op. cit.

ascends along the right flank, as far as the under surface of the liver; crosses over the abdomen to gain the left flank, along which it descends into the left iliac region, and thence through the pelvis, along the hollow of the sacrum, to terminate at the *anus*. Like the small intestine it is divided into three portions; the *cæcum*, *colon*, and *rectum*.

The *cæcum* or *blind gut* is the part of the great intestine into which the ileum opens. It is about four fingers' breadth in length, and nearly double the diameter of the small intestine. It occupies the right iliac fossa, in which it is bound down, so as not to be able to change its position. The extremity of the ileum joins the cæcum, at an angle; and if we examine the interior of the cæcum, at the point of junction, we find a valvular arrangement, which has been called *valve of Tulpius*, *valve of Bauhin*, *ileo-cæcal valve*, &c. Fig. 40 exhibits the nature of this arrangement. At the point of union of the two intestines, a soft eminence exists, flattened from above to below, and elliptical transversely, which is divided into two lips. One of these seems to belong to the ileum and colon—hence called *ileo-colic;* the other to the ileum and cæcum, and termed *ileo-cæcal*. From the disposition of these lips a valve results, so constituted, that the lips, which form it, separate when the fæcal matters pass from the small to the large intestine; whilst they approximate, cross, and completely prevent all retrogression, when the fæces tend to pass from the great intestine to the small. At the extremities of the valve are small tendons, which give it strength, and have been termed *fræna* or *retinacula of the valve of Bauhin*.

Although this valvular arrangement prevents the ready return of the excrementitious matter into the small intestine, we have many pathological opportunities for discovering that it is not effectual in all cases. In stricture of the large intestine, stercoraceous vomiting is a frequent phenomenon, and there have been cases of substances, thrown into the rectum, having been evacuated by the mouth.

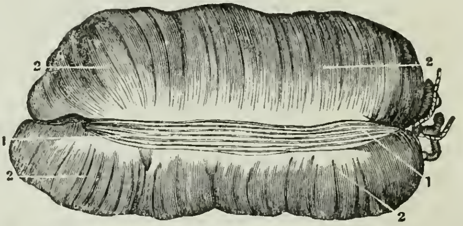
At the posterior and left side of the cæcum, a small process detaches itself, called, from its resemblance to a worm, *appendix vermiformis;* and, from its connexion with the cæcum, *appendix cæci*. It is convoluted, variable in length, and attached, by its sides, to the cæcum. Its free extremity is impervious; the other opens into the back part of the cæcum. This appendage has all the characters of an intestine. Various hypotheses have been indulged regarding its uses. Some have conceived it to be a reservoir for the fæces; but its diminutive size, in the human subject, precludes this idea: others have thought, that it secretes a ferment, necessary for fæcal formation; and others, again, a mucus for preventing the induration, that might result from the detention of the fæces in the cæcum. The opinion—that it is a mere *vestige* of the useful and double cæca, which exist in certain animals—is as philosophical as any. M. de Blainville,[1] indeed, regards it as the true cæcum; and what is named the cæcum as the commencement of the colon. It is manifestly of little importance, as it has been found wanting or obliterated in many subjects, and has been extirpated repeatedly with impunity. The cæcum is said to be wanting in all ani-

[1] De l'Organisation des Animaux, &c., Paris, 1825.

mals that hybernate. It is small in the Carnivora; very large and long in the Solidungula, Ruminantia and Rodentia; in which,—as will be seen hereafter,—there is reason to believe, that digestion of the aliment, which has escaped change higher up, occurs.

The *colon* is by much the longest of the large intestines, (Fig. 2.) It is a continuation of the cæcum, from which it cannot be distinguished; but is considered to commence at the termination of the ileum. From the right iliac fossa it ascends along the right lumbar region, over the kidney, to which it is connected. It is, in this part, called *colon dextrum*, *ascending* or *right lumbar colon.* From the kidney it passes forwards and crosses the abdomen in the epigastric and hypochondriac regions, being connected to the duodenum. This portion is called *great arch of the colon*, *colon transversum.* The right portion of the great arch is situate under the liver and gall-bladder; and hence is found tinged yellow after death, owing to the transudation of bile. The left portion of the arch is situate under the stomach; and, immediately below it, are the convolutions of the jejunum. In the left hypochondre, the colon turns backward under the spleen, and descends along the left lumbar region, anterior to the kidney, to which it is closely connected. This portion is termed *colon sinistrum*, *descending* or *left lumbar colon.* In the left iliac region, it forms two convolutions, which have been compared to the Greek ς, or to the Roman S; and hence this part of the intestine has been designated *sigmoid flexure*, *Roman* S, or *iliac turn of the colon.* This flexure varies greatly in length in different persons, extending frequently into the hypogastric region, and, in some instances, as far as the cæcum. The colon, through its whole extent, is fixed to the body by the mesocolon.

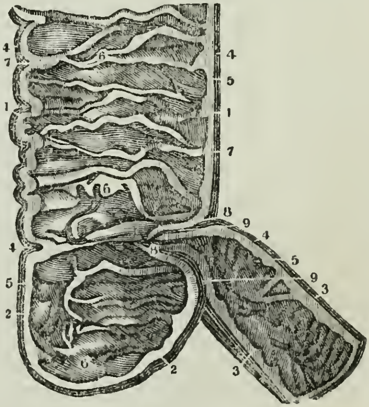
Fig. 48.



Muscular Coat of the Colon, as seen after the removal of the Peritoneum.

1, 1. One of its three bands of longitudinal muscular fibres. 2, 2. Circular fibres of the muscular coat.

Fig. 49.



Longitudinal Section of the End of the Ileum, and of the Beginning of the Large Intestine.

1, 1. Portion of the ascending colon. 2, 2. Cæcum. 3, 3. Lower portion of ileum. 4, 4. Muscular coat, covered by peritoneum. 5, 5. Areolar and mucous coats. 6, 6. Folds of mucous coat at this end of the colon. 7, 7. Prolongations of areolar coat into these folds. 8, 8. Ileo-colic valve. 9, 9. Union of the coats of the ileum and colon.

The coats of the great intestine are the same in number and structure as those of the small; but are thinner, and not as easily separable by dissection. The mucous membrane is less villous and velvety. The most characteristic difference, however, in their general appearance, is the pouched or cellular aspect of the former. These pouches are reservoirs for excrement, and in them it becomes more indurated, by the absorption of the fluid portions. In torpor of this part of the intestinal canal, the fæces are retained, at times, so long, that they form hard balls or scybala; and not unfrequently occasion the inflammation of the lining membrane of the large intestine, which constitutes dysentery. The longitudinal muscular fibres are concentrated into three ligamentous bands or fasciculi, which run the whole length of the intestine. These being shorter than the intestine, pucker it, and are the occasion of the pouched or saccated arrangement. The inner or circular muscular fibres are, like those of the small intestine, uniformly spread over the surface, but are stronger. Lastly, on the great intestine, especially the colon, are numerous processes of the peritoneum containing fat, and hence called *appendiculæ epiploïcæ* and *appendiculæ pinguedinosæ*. These are seen in greatest abundance on the right and left lumbar portions of the colon.

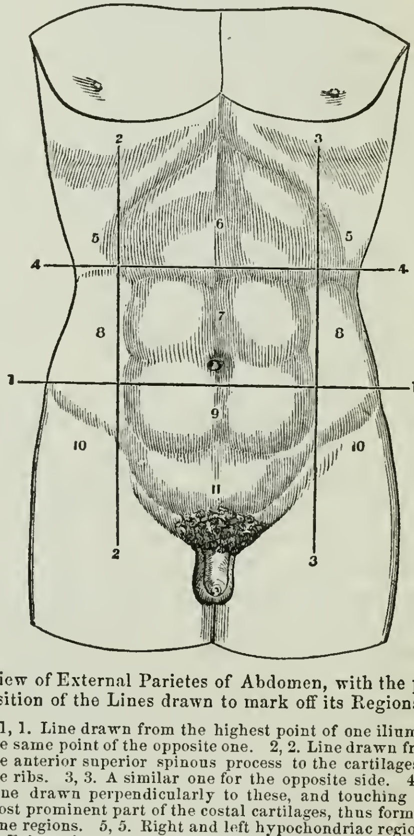
The *rectum* terminates the intestinal canal, and extends from the end of the colon to the anus. It commences about the fifth lumbar vertebra, and descends vertically into the pelvis, following the concavities of the sacrum and coccyx; and, consequently, is not straight, as its name would import. At its upper part, there are a few appendiculæ epiploïcæ; and a small duplicature of the mesentery, called *mesorectum*, attaches it to the sacrum. It differs from the other intestines in becoming wider in its progress downwards, and in its parietes being thicker. The lower part of the mucous membrane exhibits several longitudinal folds or rugæ, called "columns," which have been considered as the effect of the contraction of the circular fibres of the muscular coat. At the lower ends of the wrinkles between the columns are small pouches, from two to four lines in depth, the orifices of which point upwards. They are occasionally the seat of disease, and, when enlarged, give rise to painful itching. The nature of this affection was first pointed out by Dr. Physick, and the remedy consists in slitting them open. The longitudinal fibres of the muscular coat have a different arrangement from that which exists in the other portions of the large intestine. They are distributed over the whole surface, as in the small intestine,—or rather, as in the œsophagus. At the anus, an arrangement of the muscular coat prevails, which has been pointed out by Professor Horner.[1] The longitudinal fibres, having reached the lower margin of the internal sphincter, turn under this margin between it and the external sphincter, and then ascend upwards for an inch or two in contact with the mucous coat, into which they are finally inserted by fasciculi, which form the base of the columns of the rectum: many of the fibres, however, terminate also between the fasciculi of the circular fibres. The circular fibres are more and more marked, as they approach the outlet, and, by circumscribing the margin of the anus, they form the sphincter ani muscle. Immediately within the anus is the widest portion of the rectum; and, in this, accumulations of indurated fæces sometimes take place in old people to a surprising extent, owing to the torpor of the muscular powers concerned in the expul-

[1] General Anatomy and Histology, 8th edit., ii. 46, Philada., 1851.

sion of the fæces. The mucous coat of the rectum is thick and red, and abounds in follicles.

Lastly; there are a few muscles, which are concerned in the act of expelling the fæces. These require a short notice. 1. The *sphincter ani*, *coccygeo-anal* muscle, which keeps the anus constantly closed, except during defecation. 2. The *levator ani*, *subpubio-coccygeus*, which, with the next muscle, constitutes the floor of the pelvic and abdominal cavities. It restores the anus to its place, when pushed outwards during defecation. 3. The *coccygeus*, *ischio-coccygeus*, which assists the levator ani in supporting or raising the lower extremity of the rectum; and 4. The *transversus perinei*, *ischio-perineal* muscle, some fibres of which unite both with the bulbo-cavernosi and with the sphincter ani muscles; and, consequently, it is associated slightly with the action of both one and the other.

Fig. 50.



View of External Parietes of Abdomen, with the position of the Lines drawn to mark off its Regions.

1, 1. Line drawn from the highest point of one ilium to the same point of the opposite one. 2, 2. Line drawn from the anterior superior spinous process to the cartilages of the ribs. 3, 3. A similar one for the opposite side. 4, 4. Line drawn perpendicularly to these, and touching the most prominent part of the costal cartilages, thus forming nine regions. 5, 5. Right and left hypochondriac regions. 6. Epigastric region. 7. Umbilical region. 8, 8. Right and left lumbar regions. 9. Hypogastric region. 10, 10. Right and left iliac regions. 11. The lower part of the hypogastric, sometimes called pubic.

In regard to the intestinal canal, we find, that man holds a medium place between the carnivorous and herbivorous animal, although approximating more to the latter. In the carnivorous—for reasons hereafter mentioned—it is unnecessary that the food should remain long; accordingly, the canal is very short. In the herbivora, on the other hand, and for opposite reasons, the canal is long, and there is generally a large cæcum and a pouched colon. Cuvier[1] has given tables of the length of the digestive tube, compared with that of the body; but where the comparison has been applied to man, the length of the body has included that of the legs. Instead, therefore, of the canal, in him, being considered to bear the proportion of six to one, it ought to be doubled, or be regarded as twelve to one; a proportion somewhat greater than prevails in the simiæ or ape tribe. It is not, however, always in length, that the canal of the herbivorous exceeds that of the omnivorous animal; but as a general rule, it may be affirmed, that its capacity is much more considerable.

[1] Leçons d'Anatomie Comparée, Paris, 1799.

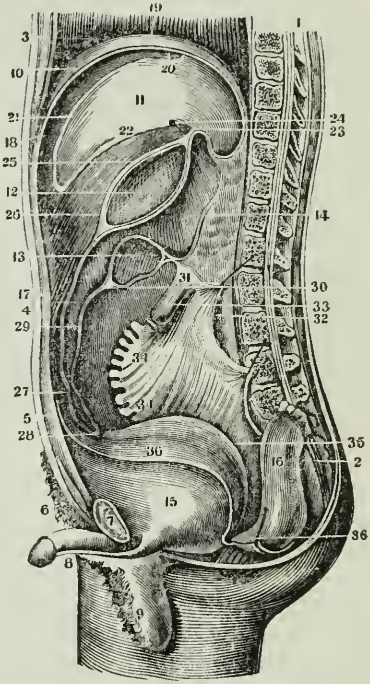
5. The *abdomen*, in which the principal digestive organs are situate, and whose parietes exert considerable influence on the digestive function, requires a brief description. It is the division of the body, which is betwixt the thorax and pelvis; is bounded, above, by the arch of the diaphragm; behind, by the vertebral column; laterally, and anteriorly, by the abdominal muscles; and, below, by the ossa ilii, os pubis, and the cavity of the pelvis.

To connect the knowledge of the internal parts of the abdomen with the external, it is customary to mark certain arbitrary divisions on the surface, called *regions*. (Fig. 50.) The *epigastric region* is at the upper portion of the abdomen, under the point of the sternum, and in the angle formed by the cartilages of the ribs. The *hypochondriac regions* are covered by the cartilages of the ribs. These three regions—the epigastric, and right and left hypochondre—constitute the upper division of the abdomen, in which are seated the stomach, liver, spleen, pancreas, duodenum, and part of the arch of the colon. The space surrounding the umbilicus, between the epigastric region and a line drawn from the crest of one os ilii to the other, is the *umbilical region*. Here the small intestines are chiefly situate. This region is bounded by lines, raised perpendicularly to the spine of the ilium; and the lateral portions on the outside of these lines, form the *iliac regions*, behind which, again, are the *lumbar regions* or *loins*. In these, the colon and kidneys are chiefly situate. The *hypogastric* is, likewise, divided into three regions,—the *pubic* in the middle, in which is the bladder; and an *inguinal* on each side.

The muscles that constitute the abdominal parietes, are,—first of all, *above*, the diaphragm, which is the boundary between the thorax and abdomen, convex towards the chest, and considerably concave towards the abdominal cavity. *Below*, if we add the pelvic cavity,—which, as it contains the rectum, and muscles concerned in the evacuation of the fæces, it may be proper to do,—the cavity is bounded by the perineum, formed chiefly of the levatores ani and coccygei muscles. *Behind*, *laterally*, and *anteriorly*, from the lumbar vertebræ round to the umbilicus, the parietes consist of planes of muscles, and aponeuroses in superposition, united at the median line, by a solid, aponeurotic band, extending from the cartilago ensiformis of the sternum to the pubes, called *linea alba*. The *abdominal muscles*, properly so called, are,—reckoning the planes from within to without,—the greater *oblique muscle*, *lesser oblique*, and *transversalis*, which are situate chiefly at the sides of the abdomen; and the *rectus* and *pyramidalis*, which occupy the anterior part. The *greater oblique*, *obliquus externus*, *costo-abdominalis*; *lesser oblique*, *obliquus internus*, *ilio-abdominalis*; and *transversalis*, *transversus abdominis*, *lumbo-abdominalis*, support and compress the abdominal viscera; assist in the evacuation of the fæces and urine, and in the expulsion of the fœtus; besides other uses, connected with respiration and the attitudes. The *rectus*, *pubio-sternalis* or *sterno-pubialis*; and the *pyramidalis* or *pubio-subumbilicalis*, are more limited in their action, and compress the forepart of the abdomen; besides having other functions.

Lastly, a serous membrane—the *peritoneum*—lines the abdomen, and gives a coat to most of the viscera. The mode, in which its various reflections are made, is singular, but easily intelligible from the accompanying figure (Fig. 51). It has neither beginning nor end, constitut-

Fig. 51.



1. Section of the spinal column and canal. 2. Section of the sacrum. 3. Section of the sternum, &c. 4. Umbilicus. 5. A section of the linea alba and abdominal muscles. 6. Mons veneris. 7. Section of the pubis. 8. Penis divided at the corpora cavernosa. 9. Section of the scrotum. 10. Superior right half of the diaphragm. 11. Section of the liver. 12. Section of the stomach, showing its cavity. 13. Section of the transverse colon. 14. Section of the pancreas. 15. Section of the bladder, deprived of the peritoneum. 16. Rectum cut off, tied and turned back on the promontory of the sacrum. 17. Peritoneum covering the anterior parietes of the abdomen. 18. Peritoneum on the inferior under side of the diaphragm. 19. Peritoneum on the convex side of the diaphragm. 20. Reflection of peritoneum from diaphragm to liver. 21. Peritoneum on front of liver. 22. The same, on its under surface. 23. Hepato-gastric omentum. 24. A large piu passed through the foramen of Winslow into the cavity behind the omentum. 25. Anterior face of the hepato-gastric omentum, passing in front of the stomach. 26. The same membrane leaving the stomach to make the anterior of the four layers of the great omentum. 27, 28. Junction of the peritoneum from the front and back part of the stomach, as they turn to go up to the colon. 29. Gastro-colic, or greater omentum. 30. Separation of its layers, so as to cover the colon. 31. Posterior layer passing over the jejunum. 32. Peritoneum in front of the right kidney. 33. Jejunum cut off and tied. 34, 34. Mesentery cut off from the small intestines. 35. Peritoneum reflected from the posterior paries of the bladder to the anterior of the rectum. 36. Cul-de-sac between the bladder and the rectum.

Reflections of the Peritoneum, as shown in a Vertical Section of the Body.

ing, like all serous membranes, a shut sac; and, in reality, having no viscus within it. If we assume the diaphragm as the part at which it commences, we find it continued from the surface of that muscle over the abdominal muscles, 5; then reflected, as exhibited by the curved line, over the bladder, 15; and, in the female, over the uterus; thence over the rectum, 16; the kidney, enveloping the intestine, 13, and constituting, by its two laminæ, the mesentery, 34; giving a coat to the liver, 11; and receiving the stomach, 12, between its duplicatures. The use of this membrane is to fix and support the different viscera; to constitute, for each, a pedicle, along which the vessels and nerves may reach the intestine; and to secrete a fluid, which enables them to move readily upon each other. When we speak of the cavity of the peritoneum, we mean the inside of the sac; and when it is distended with fluid, as in ascites, the fluid is contained between the peritoneum lining the abdominal muscles, and that which forms the outer coat of the intestines. The *omenta* or *epiploa* are fatty membranes, which hang over the face of the bowels; and are reflections, formed by the peritoneum after it has covered the stomach and intestines. Their names sufficiently indicate their position:—the *lesser epiploon* or *omentum*,—the *omentum hepato-gastricum;* the *greater* or *gastro-colic;* and the *appen-*

dices or *appendiculæ epiploicæ;* which last have already been referred to, and may be regarded as so many small epiploons.

The abdomen is entirely filled by the contained viscera. There are several apertures in it; three, above, in the diaphragm, for the passage of the œsophagus, vena cava inferior, and aorta; one anteriorly in the course of the linea alba, which is closed after birth,—the *umbilicus;* and two anteriorly and inferiorly; the one—the *abdominal, inguinal;* or *supra-pubian ring*—which gives passage to the vessels, nerves, &c., of the testicle; and the other—the *crural arch*—through which the vessels and nerves pass to the lower extremity. Lastly, two others exist in the inferior paries, for the passage of the obturator vessels and nerves, and sciatic vessels and nerves, respectively.

Such is a brief view of the various organs concerned in digestion. To this might have been added the general anatomy of the liver and pancreas,—each of which furnishes a fluid, that is a material agent in the digestive process,—and of the spleen, which has been looked upon by many as inservient, in some manner, to the same function. As, however, the physiology of these organs will be considered in another place, we defer their anatomy for the present.

2. FOOD OF MAN.

The articles, inservient to the nourishment of man, have usually been considered to belong entirely to the animal and vegetable kingdoms; but there seems to be no sufficient reason for excluding those articles of the mineral kingdom that are necessary for the due constitution of the different parts of the body. Generally, the term *food* or *aliment* is applied to substances, which, when received into the digestive organs, are capable of being converted into chyle; but, from this class again, the products of the mineral kingdom—as chloride of sodium, phosphorus, sulphur, and lime, either in combination or separately—cannot, with entire propriety, be excluded. There are numerous tribes who feed at particular seasons more especially on mineral substances. Kessler affirms, that the quarriers on the Kyffhäuser, in northern Thuringia, spread a Steinbutter—"rock butter," on bread, which they eat with appetite; and Von Humboldt relates, among many other instances, that of the Ottomacs, who, during the periodical rise of the Orinoco and Meta, when the taking of fish ceases—a period of two or three months' duration—swallow great quantities of earth. They found piles of clay-balls in pyramidal heaps in the huts, and Humboldt was informed, that an Ottomac would eat from three-quarters of a pound to a pound and a quarter in a day. Some of this earth was analyzed by M. Vauquelin, and found to contain no organic matter. It would appear, that the practice of eating earth exists in many parts of the torrid zone, among indolent nations, who inhabit the finest and most fertile regions of the globe. But it is not confined to them; for the same writer affirms, that in the north, by information communicated by Berzelius and Retzius, hundreds of cartloads of earth containing infusoria are annually consumed by the country people in the most remote parts of Sweden as bread meal, and even more as a luxury—like tobacco—than as a necessary. In Finland, the earth is occasionally mixed with the bread. It consists of empty shells of animalcules, so small and soft as not to cranch perceptibly between the teeth, filling the stomach, but affording no real nutriment. Many similar cases are recorded by Humboldt.[1]

Animals are often characterized by the kind of food on which they subsist. The *carnivorous* feed on flesh; the *piscivorous* on fish; the *insectivorous* on insects; the *phytivorous* on vegetables; the *granivorous* on seeds; the *frugivorous* on fruits; the *graminivorous* and *herbivorous* on grasses; and the *omnivorous* on the products of both the animal and the vegetable kingdom. In antiquity, we find whole tribes designated according to the aliment they chiefly used. Thus, there were the Æthiopian and Asiatic *ichthyophagi* or fish-eaters; the *hylophagi*, who fed on the young shoots of trees; the *elephantophagi*, and *struthiophagi*, elephant and ostrich-eaters, &c. &c.

We have already shown, that the digestive apparatus of man is intermediate between that of the carnivorous and the herbivorous animal; that it partakes of both, and that man may, consequently, be regarded *omnivorous;* that is, capable of subsisting on both the products of the animal and the vegetable kingdom;—an important capability, seeing, that he is destined to live in arctic regions, in which vegetable food is not to be met with, as well as in the torrid zone, which is more favourable for vegetable than animal life.

The nature of the country must, to a great extent, regulate the food of its inhabitants; for although commerce can furnish articles of luxury, and many which are looked upon as necessaries, no nation is entirely indebted to it for its supplies. Besides, numerous extensive tribes of the human family are denied the advantages of commerce, and compelled to subsist on their own resources. This is the main cause why the Esquimaux, Samoiedes, &c., live wholly on animal food; and why the cocoa-nut, plantain, banana, sago, yam, cassava, maize and millet, form chief articles of diet with the natives of torrid regions.

In certain countries, the scanty supply of the useful and edible animals has given occasion to certain prohibitory dietetic rules and regulations, which have been made to form part of the religious creed, and, of course, are most scrupulously observed. Thus, in Hindostan, animal food is not permitted to be eaten; but the milk of the cow is excepted. Accordingly, to insure the necessary supply of this fluid, the cow is made sacred; and its destruction a crime against religion. Amongst the laws of the Egyptians are similar edicts, but they seem to have been chiefly enacted for political purposes, and not in consequence of the unwholesome character of the interdicted articles. The same remark applies to many of the dietetic rules of Moses, for the regulation of the tables of the Hebrews. Blood was forbidden, in consequence, probably, of the fear entertained, that it might render the people too familiar with that fluid, and diminish the horror inculcated against shedding it; the parts of generation were excluded from the table, because the taste, if indulged, might interfere with the reproduction of the species, &c. &c.

We have said, that, in his arrangement of the digestive organs, man is intermediate between the carnivorous and the herbivorous animal.

[1] Ansichten der Natur; translated under the title of Aspects of Nature, by Mrs. Sabine, Amer. edit., p. 159, Philadelphia, 1849.

Not the slightest ground is afforded by anatomy for the opinion of Rousseau, that man was originally herbivorous; or for that of Helvetius,[1] that he was exclusively carnivorous. Broussonet affirms, that he is more herbivorous than carnivorous, since, of his thirty-two teeth, twenty resemble those of the herbivorous, whilst twelve only resemble those of the carnivorous animal. Accordingly, he infers, that, in the origin of society, the diet of man must have been exclusively vegetable. Mr. Lawrence,[2] too, concludes, that, whether we consider the teeth and jaws, or the immediate instruments of digestion, the human structure closely resembles that of the simiæ—the great archetypes, according to Lord Monboddo[3] and Rousseau, of the human race,—all of which are, in their natural state, herbivorous.

Again:—a wide discrepancy between man and animals is observed in the variety of their aliments. Whilst the latter are generally restricted to either the animal or vegetable kingdom, and to but a small part of either, man embraces an extensive range, and by means of his culinary inventions can convert a variety of articles from both kingdoms into materials of sustenance. But it has been argued by those, who are sticklers for *the natural*, that man probably confined himself, primitively, like animals, to one kind of food; that he adhered to this whilst he remained in his *natural state*, and that his omnivorous practices are a proof of his degeneracy. Independently, however, of all arguments deduced from organization, experience sufficiently shows the inaccuracy of such assertions. If we trace back nations to their state of infancy, we find, that then, as in their more advanced condition, their diet was animal, or vegetable, or both, according to circumstances. Of this fact we have some signal examples in a part of the globe where the lights of civilization have penetrated to a less extent than in most others; and where the influence of circumstances that prevailed in ancient periods has continued, almost unmodified, until the present time. Agatharchides[4] describes the rude tribes, who lived on the coast of the Red Sea, and subsisted on fish, under the name *ichthyophagi*. Along both banks of the Astaboras, which flows on one side of Meroë, dwelt another nation, who lived on roots of reeds growing in the neighbouring swamps. These roots they cut to pieces with stones, formed them into a tenacious mass, and dried them in the sun. Close to them were the *hylophagi*, who lived on the fruits of trees, vegetables growing in the valleys, &c. To the west of these were hunting nations, who fed on wild animals, which they killed with the arrow. There were, also, other tribes, who lived on the flesh of the elephant and ostrich,—*elephantophagi* and *struthiophagi*. Besides these, he mentions another and less populous tribe, who fed on locusts, which came in swarms from the southern and unknown districts. The mode of life, with the tribes described by Agatharchides, does not seem to have varied for the last two thousand years. Although cultivated nations are situated around them, they have made no progress themselves. Hylophagi are still to be met with. The Dobenahs, the most powerful tribe amongst

[1] De l'Homme, ii. 23, Londres, 1775.
[2] Lectures on Physiology, Zoology, &c., p. 221, London, 1819.
[3] On the Origin and Progress of Language, Pt. i. Book 2, Chap. 2, Edinburgh, 1773.
[4] De Rubro Mare, in Hudson's Geograph. Minor., i. 37.

the Shangallas, still live on the elephant; and, farther to the west, dwells a tribe, which subsists in the summer on the locust; and, at other seasons, on the crocodile, hippopotamus, and fish.[1]

In the infancy of society, as in his own infancy, man was perhaps almost wholly carnivorous; as the tribes least advanced in civilization are at the present day. For a time, he may, in most situations, have confined himself to the vegetable banquet prepared for him by his bounteous Maker; but, as population increased, the means of subsistence would become too scattered for him, and it would be necessary to crowd together a number of nutritious vegetables into a small space, and to cultivate the earth, so as to multiply its produce; but this would imply the existence of settled habits and institutions which could only arise after society had made progress. Probably, much before this period, it would have been discovered, that certain of the beasts of the forest, and of the birds of the air, and some of the insect tribes, could minister to his wants, and form agreeable and nutritious articles of diet; and thus would arise their adoption as food. On the coasts of the ocean, animal food was perhaps employed from the period of their first settlement; as well as on the banks of the large streams which are so common in Asia,—the cradle of mankind. The fish, left upon the land after the periodical inundations of the rivers, or thrown on the sea-coast, would minister to their necessities, without the slightest effort on their part; and, hence, they would have but little incentive to mental or corporeal exertion. This is the cause of the abject condition of the ichthyophagous tribes of old; and of their comparatively low state of civilization at the present day.[2] Again:—savages, in various parts of the globe, live by the chase or the fishery; and must, consequently, be regarded as essentially carnivorous. It would not, however, be justifiable, to regard barbarism as the *natural* state of man; nor is it clear what the different writers on this point of anthropology have meant by the term. The Author of nature has invested him with certain prerogatives, one of which is the capability of rendering the organized kingdom subservient to his wishes and necessities; and, by the invention of the culinary art, of converting various organized bodies into wholesome and agreeable articles of diet, which thus become as *natural* to him as the restriction to one species of aliment is to the animal.

It has been remarked, that the exclusive or predominant use of animal or of vegetable food has a manifest effect upon the physical and moral powers. Buffon affirms, that if man were obliged to abstain from flesh in our climates, he could not exist, nor propagate his kind. Others, again, have depicted a state of ideal innocence, in the infancy of society, when he lived, as they conceive, entirely on vegetables;

> "His food the fruits; his drink the crystal well;"

unsolicitous for the future in consequence of the abundant subsistence spread before him; independent; and always at peace with his fellows, and with animals; but he gradually sacrificed his liberty to the bonds

[1] Bruce, Travels, 3d edit., v. 83.
[2] The Author, in Amer. Med. Intelligencer, i. 99, Philad., 1838.

of society; and cruelty, with an insatiable appetite for flesh and blood, were the first fruits of a depraved nature. Either immediately or remotely, all the physical and moral evil, by which mankind are afflicted, arose from these carnivorous practices. "The principal patrons of this twaddle, in modern times"—says Dr. Fletcher—"to say nothing of Pythagoras and the ancients—have been Gassendi, Rousseau, Wallis, Lamb, and Newton; the last of whom, in the plenitude of his infatuation, asserts that *real* men have never yet been seen, nor ever will be, till they shall be content to subsist entirely on herbs and fruits and distilled water."[1] In point of fact, we find, that the inhabitants of countries, in which mankind are accustomed to be omnivorous, or to unite animal with vegetable diet, are those most distinguished for both mental and corporeal endowments. The tribes, which feed altogether on animal food,—as the Laplanders, Samoiedes, Esquimaux, &c.,—are far inferior, in both these respects, to the European, or Europeo-American; and the same may be said, although not to the like extent, of the various tribes in whose diet animal food predominates,—as the Indian inhabitants of our own continent. A similar remark is applicable to those, who live almost exclusively on vegetables, as the Hindoos, millions of whom are kept in subjection by a few Europeans.[2]

Attempts have frequently been made to refer the nutrient properties of all articles of diet to a particular principle of a constant character, which, alone, of all the elements, is entirely capable of assimilation. Haller[3] conceived this to be jelly;—Dr. Cullen[4] thought it to be oily, or saccharine, or what seemed to be a combination of the two;—Becker, Stahl, Fordyce,[5] &c., to be mucilage; M. Dumas,[6] mucus; and M. Hallé, a hydro-carbonous oxide very analogous to gummi-saccharine matter![7] It is probable, that there is no such special principle as the one contended for; and that, in all cases, in the formation of the chyle or reparative fluid, which is separated from it, the food is resolved into its elements. To this conclusion we are necessarily impelled, when we reflect, that chyle can be formed from both animal and vegetable substances. In an early part of this work, occasion was taken to mention, that all organized tissues, animal and vegetable, are reducible into nearly the same ultimate elements,—oxygen, hydrogen, carbon, and nitrogen. Great light has been thrown on this subject, in recent periods, by the labours of the organic chemist. These have shown, that the chief proximate principles of animal tissues, and those that have been regarded as highly nutritious amongst vegetables, have almost identically the same composition; and are modifications of protein.[8] The following tables from Liebig[9] exhibit the striking

[1] Rudiments of Physiology, Part ii., *a*. p. 121, Edinb., 1836.
[2] Lawrence's Lectures, edit. cit., p. 216.
[3] Elementa Physiologiæ, Lib. xix., Sect. 3, Bernæ, 1764.
[4] Institutions of Medicine, Part i., Physiology, § 211, Edinb., 1785.
[5] Treatise on the Digestion of Food, p. 84, 2d edit., Lond., 1791.
[6] Principes de Physiologie, i. 187, Paris, 1806.
[7] Tiedemann, Physiologie des Menschen, iii. 95, Darmstadt, 1836.
[8] See page 39.
[9] Animal Chemistry, Gregory's and Webster's edit., pp. 100, 283, and 301, Cambridge, Mass., 1842.

similarity in constitution, and in the proportion of constituents, of different animal and vegetable compounds of organization.

Animal proximate principles, according to Mulder.

	Albumen.	Fibrin.	Casein.
Carbon,	54·84	54·56	54·96
Hydrogen,	7·09	6·90	7·15
Nitrogen,	15·83	15·72	15·80
Oxygen,	21·23	22·13	21·73
Sulphur,	0·68	0·33	0·36
Phosphorus,	0·33	0·36	
	100·00	100·00	100·00

Vegetable proximate principles, according to Scherer and Jones.

	Albumen, from wheat.	Fibrin.	Casein or Legumin.
Carbon,	55·01	54·603	54·138
Hydrogen,	7·23	7·302	7·156
Nitrogen,	15·92	15·809	15·672
Oxygen, Sulphur, Phosphorus,	21·84	22·286	23·034
	100·00	100·000	100·000

As the different parts of organized bodies contain a considerable portion of nitrogen, a question has arisen regarding its source; some believing, that it is obtained from the food, others by respiration.

M. Magendie[1] instituted experiments with the view of determining the nutritive qualities of non-nitrogenized substances. They consisted in feeding animals, for the necessary time, on a diet whose chemical composition was rigidly determined. He fed a dog, three years old and in good condition, on pure white sugar and distilled water. For seven or eight days, the animal appeared to thrive well, was lively, and ate and drank with avidity. In the second week, it began to fall off, although its appetite continued good, and it ate six or eight ounces of sugar in the twenty-four hours. In the third week, it became emaciated, its strength diminished, its gaiety was gone, and its appetite impaired. An ulcer formed on each eye, at the centre of the cornea, which subsequently perforated it, and allowed the humours to escape. The emaciation, as well as loss of strength, went on progressively increasing; and, although the animal ate daily three or four ounces of sugar, the debility became so great, that it could neither chew, swallow, nor execute the slightest movement. It died on the thirty-second day of the experiment. On dissection, the fat was found to have entirely disappeared; the muscles were reduced to less than five-sixths of their ordinary size; the stomach and intestines were much diminished, and powerfully contracted; and the gall and urinary bladders filled with fluids not proper to them. These were examined by M. Chevreul, who found them to possess almost all the characters of the bile and urine of herbivorous animals. The urine, in place of being acid, as it is in the carnivora, was sensibly alkaline, and presented no trace of uric acid or phosphates. The bile contained a considerable proportion of picromel, like that of the ox and herbivora in general.

[1] Précis Élémentaire, 2de édit., ii. 488, Paris, 1825.

The excrements contained very little nitrogen, which they usually do in abundance.

A second dog was subjected to the like regimen, and with similar results. He died on the thirty-fourth day of the experiment. A third experiment, having eventuated in the same manner, M. Magendie concluded that sugar alone is incapable of nourishing the dog. In all these cases, ulceration of the cornea occurred, but not exactly at the same period of the experiment. He next endeavoured to discover, whether these effects might not be peculiar to sugar; or whether non-nitrogenized substances, generally considered nutritious, might not act in the same manner. He took two young and vigorous dogs, and fed them on olive oil and distilled water. For fifteen days they were apparently well; but, after this, the same train of phenomena supervened as in the other cases, except that there was no ulceration of the cornea. They died about the thirty-sixth day of the experiment. Similar experiments were made with gum Arabic, and with butter—one of the animal substances that do not contain nitrogen. The results were identical.

Although the character of the excrements passed by the different animals indicated that the substances were well digested, M. Magendie was desirous of establishing this in a positive manner. Accordingly, after having fed animals for several days on oil, gum, or sugar, he opened them, and found that each of these substances was reduced to a particular kind of chyme in the stomach; and that all afforded an abundant supply of chyle; that from oil being of a manifest milky appearance, and that from gum or sugar, transparent, opaline, and more aqueous than the chyle from oil; facts which prove, that if the various substances did not nourish the animals, the circumstance could not be attributed to their not having been digested. These results, M. Magendie thought, render it likely, that the nitrogen, found in different parts of the animal economy, is originally obtained from the food. This, however, is doubtful. We have no proof, that the animals died simply from privation of nitrogen. It is, indeed, probable, that it had little or no agency in the matter, for there seems to be no sufficient reason why it should not have been procured from the air in respiration, as well as from that contained between the particles of the sugar, where this substance was administered. It must be recollected, moreover, that the subjects of these experiments were dogs;—animals which, in their natural state, are carnivorous, and, in a domestic state, omnivorous; and that they were restricted to a diet foreign to their nature, and one to which they had not been accustomed. Ought we, under such circumstances, to be surprised, that they should sicken, and fall off?

In the period that elapsed between the publication of the first and second editions of his *Précis Élémentaire de Physiologie*, M. Magendie found that his deductions were not, perhaps, as absolute or demonstrative as he had at first imagined; and additional experiments induced him to conclude,— as Dr. Bostock[1] afterwards did, without being aware, apparently, of his observation,—"that variety and multiplicity of

[1] Physiology, 3d edit., p. 561, Lond., 1836.

articles of food constitute an important hygienic rule." "This," M. Magendie[1] adds, "is indicated to us by our instinct, as well as by the changes that wait upon the seasons, as regards the nature and kind of alimentary substances." The additional facts, detailed by M. Magendie, are the following:—A dog, fed at discretion on pure wheaten bread, and drinking common water, does not live beyond fifty days; whilst another, fed exclusively on military bread—*pain de munition*—seems to suffer in no respect. Rabbits or Guinea-pigs, fed on a single substance, as wheat, oats, barley, cabbage, carrots, &c., commonly die, with every mark of inanition, in a fortnight; and, at times, much earlier. When the same substances are given together, or in succession, at short intervals, the animals continue in good keeping. An ass, fed on rice, lived only fifteen days, refusing his food for the last few days; whilst a cock was fed upon boiled rice for several months without his health suffering. Dogs, fed exclusively on cheese, and others on hard eggs, lived for a long time; but they were feeble and lean, losing their hair, and their whole appearance indicated imperfect nutrition. The substance, which, when given alone, appeared to support the rodentia[2] for the greatest length of time, was muscular flesh.

Lastly, M. Magendie found, that if an animal had subsisted for a certain time on a substance, which, taken alone, is incapable of nourishing it,—on white bread, for instance, for forty days,—it is useless, at the end of that time, to vary his nourishment, and restore him to his accustomed regimen. He will feed greedily on the new food presented to him; but continues to fall off; and dies at the same period as he would probably have done, if maintained on his exclusive regimen. That these effects are not owing to privation of nitrogen, the same observer[3] has since been amply satisfied. As chairman of a committee appointed to inquire into the nutritive properties of gelatin, he reported that gelatin, albumen, and fibrin—all of which are highly nitrogenized—when taken separately, nourish animals for a limited period only, and imperfectly. They generally soon excite so insurmountable a disgust that the animals would rather die than partake of them. These experiments led to the too hasty conclusion, that the gelatinous tissues are incapable of conversion into blood. "The gelatinous substance," says Liebig,[4] "is not a compound of protein; it has no sulphur, no phosphorus, and contains more nitrogen or less carbon than protein. The compounds of protein, under the influence of the vital energy of the organs that form the blood, assume a new form, but are not altered in composition; whilst these organs, as far as our experience reaches, do not possess the power of producing compounds of protein, by virtue of any influence, from substances that contain no protein. Animals, which were fed exclusively on gelatin, the most

[1] Op. citat., ii. 494.

[2] The *rodentia* are gnawing animals, having large incisors in each jaw, with which they divide hard substances. They are the *rongeurs* of the French naturalists. The squirrel, mouse, rat, Guinea-pig, hare, rabbit, beaver, kangaroo, porcupine, &c., belong to this division.

[3] Comptes Rendus, Août, 1841. Similar results were obtained by the Amsterdam Commission, Het Instituut, No. ii. 1843, pp. 97–114, cited by Mr. Paget, Brit. and For. Med. Rev., April, 1845, p. 563.

[4] Animal Chemistry, Amer. edit., by Webster, p. 124, Cambridge, Mass., 1842.

highly nitrogenized element of the food of carnivora, died with symptoms of starvation." "In short," he adds, "gelatinous tissues are incapable of conversion into blood." Such too, seems to be the opinion of Professor Bérard.[1] Yet it has been shown above, that fibrin and albumen—both compounds of protein—when exhibited singly to animals, nourished them as imperfectly as gelatin; and there is some reason to believe, that it is mainly on chemical considerations that the value of gelatin as a nutriment has been much underrated. "Such persons only," says Professor Mulder,[2] "as are under the influence of prejudice (making their experiments with dogs—animals which, according to the account of the gelatin committee, prefer to starve in the midst of gelatin, rather than touch it), such persons only as deny the results of innumerable observations, will refuse to gelatin its place among useful nutritive substances." And he adds: "I have thought it necessary, before closing this short account of gelatin, to express my opinion of the experiments by which pure gelatin is rejected as food:—namely, that these experiments have taught me nothing but how experiments ought *not* to be made." It is somewhat singular, too, that most of those who deny much nutrient property to gelatin are of opinion, that the nutritious properties of different articles of vegetable food may be generally estimated by the proportion of nitrogen they contain, and on this principle tables have been formed by several experienced chemists,—by Boussingault, Schlossberger, Kemp,[3] and Professor Horsford,[4] of Cambridge, Massachusetts. The latter gentleman, especially, has published the results of elaborate investigations into the nature of different kinds of vegetable food, based upon the amount of nitrogen. The tables of Boussingault and Horsford are considered by Professor Frerichs,[5] of value; whilst those of Schlossberger and Kemp are declared to be practically useless, because no regard was paid to the quantity of water in the fresh condition; and for the strange reason, "that the nitrogen found in most of the substances analyzed that contain gelatin is no measure of the quantity of the hæmatogenetics or blood-forming constituents!"

Independently of showing the necessity of variety of food for animal sustenance, the experiments of M. Magendie exhibit some singular anomalies; and sufficiently demonstrate, that we have yet much to learn on the subject. A great deal, doubtless, depends on the habits of the particular animal or individual; and on the morbid effects excited by completely changing the function of assimilation. It has been long known, that if a man, previously habituated to both animal and vegetable diet, be restricted exclusively to one or the other, he will fall off, and become scorbutic; and yet, that he is capable of subsisting on either one or the other exclusively, provided the restriction has been enforced from early infancy, has been sufficiently shown by the refer-

[1] Archives Générales de Médecine, Février, 1850, p. 247.

[2] The Chemistry of Vegetable and Animal Physiology, by G. J. Mulder, &c., p. 328, Edinb. and Lond., 1849.

[3] Annal. der Chemie und Pharmacie, B. lvi. s. 78–94; see also, Philosophical Magazine for Nov., 1845.

[4] Philosophical Magazine, for Nov., 1846, p. 365.

[5] Art. Verdauung, in Wagner's Handwörterbuch der Physiologie, 19te Lieferung, s. 732, Braunschweig, 1848.

ence made to carnivorous and herbivorous tribes existing in different regions of our globe. The importance of variety of diet is illustrated by the experiments made by Dr. Stark,[1] upon his own digestive powers, and to which he ultimately became a martyr. His object was to discover the relative effect of various simple substances, when used exclusively for a long space of time as articles of food. The system, he found, was in all cases reduced to a state of extreme debility, and there was not a single aliment, that was capable, of itself, of sustaining the vigour of the body for any considerable period. By this kind of regimen Dr. Stark is said to have so completely ruined his own health, as to bring on premature death.

It would seem, too, that for continued sustenance, a due supply of vegetable food, which is not deprived of its organic acids and salts, must be permitted; hence the production of scurvy by the want of fresh vegetables, and its removal by a proper admixture of the same, which must either be eaten raw, or so cooked that they may not be deprived of their saline constituents.[2] Occasionally, too, where scurvy has arisen under the exclusive use of animal diet, it has disappeared when a fresh article of nitrogenized diet has been obtained. Thus, his friend Dr. Kane, of the United States Navy, informed the author that during the first expedition to the Arctic regions in search of Sir John Franklin, when the sailors were suffering with scorbutus, and the lesser awk visited the region in its periodical migration, the fresh, uncooked flesh of the bird soon dispelled every symptom of the malady.

In accordance with his views, that nitrogenized food is alone capable of forming organized tissue; and that the non-nitrogenized food is inservient to respiration only, Liebig thus classifies aliments:—

Nitrogenized Food or Plastic Elements of Nutrition.	*Non-nitrogenized Food or Elements of Respiration.*	
Vegetable Fibrin,	Fat,	Pectin,
" Albumen,	Starch,	Bassorin,
" Casein,	Gum,	Wine,
Flesh,	Cane Sugar,	Beer,
Blood.	Grape Sugar,	Spirits.
	Sugar of Milk,	

These views, however, are more chemical than physiological, and certainly have always been considered by the author to demand proof which has not been sufficiently afforded. They are not confirmed by what is observed in chylification. In the small chyliferous vessels, more fat, which is a non-nitrogenized substance, is found than can be accounted for by the adipose matter in the food; and of the conversion of the amylaceous and saccharine matters in the food to oil during the digestive function a striking example has been published by M. Köss.[3] A workman was killed on a railroad after having eaten a full meal of bread and grapes only. On examining his body, the process of chymification was found to have been in full activity; and in those portions of the small intestine, which the chyme had reached, the mucous membrane was dotted with white points, which, on closer

[1] The Works of the late Wm. Stark, M. D., &c., by Dr. J. C. Smyth, Lond., 1787.

[2] British and Foreign Medico-Chirurg. Rev., Oct. 1848, p. 473.

[3] Cited in London Med. Gazette, Oct., 1846. See, on this subject, Moleschott, Physiologie des Stoffwechsels im Pflanzen und Thieren, S. 203, Erlangen, 1851.

examination, were found to be owing to drops of oil in the epithelial cells surrounding the extremities of the villi. As the chyle proceeds along the lacteals, the proportion of fat becomes less and less, whilst that of the nitrogenized matters increases; hence nitrogen must have been obtained, and a conversion have taken place of non-nitrogenized into nitrogenized matters. (See PHYSIOLOGY OF CHYLOSIS.)

The implicit believers in the views of Liebig, have affirmed, as a matter of course, that fat can only be an "element of respiration;" yet it appears to be necessary in all cell formation; and, in the yolk, to be an aliment destined for the formation of every tissue in the animal; as starch—an equally non-nitrogenized article—is in the case of the seed of the vegetable. Moreover, it enters largely into the composition of neurine. These, and analogous considerations, have caused some of those who hastily embraced the doctrine of the distinguished chemist on this subject to pause, and even to retrace their steps;[1] and evidence enough seems to exist to cause it to be abandoned.[2]

The alimentary substances, employed by man, have generally been classed either according to the ultimate chemical elements entering into their composition; or to the chief proximate principle or compound of organization. In the former case, they have been grouped into:—1, those that contain nitrogen, carbon, hydrogen, and oxygen;—2, those that contain carbon, hydrogen, and oxygen; and 3, those that contain neither nitrogen nor carbon. The first class will comprise most animal and many vegetable substances; the second, vegetable substances chiefly; whilst water is perhaps the only alimentary matter that belongs to the third.

The division proposed by M. Magendie,[3] and adopted by Dr. Paris,[4] is according to the proximate principles, which predominate in the aliment.

1. *Amylaceous aliments;* wheat, barley, oats, rice, rye, Indian corn, potato, sago, salep, peas, haricots, lentils, &c.
2. *Mucilaginous aliments;* carrot, salsify, beet, turnip, asparagus, cabbage, lettuce, artichoke, melon, &c.
3. *Saccharine aliments;* the different kinds of sugar, figs, dates, raisins, &c.
4. *Acidulous aliments;* the orange, currant, cherry, peach, raspberry, strawberry, mulberry, grapes, prunes, pears, apples, tomatos, &c.
5. *Oily and fatty;* cocoa, olives, sweet almonds, hazelnuts, walnuts, animal fats, oils, butter, &c.
6. *Caseous aliments;* the different species of milk, cheese, &c.
7. *Gelatinous aliments;* the tendons, aponeuroses, skin, areolar tissue, the flesh of very young animals, &c.
8. *Albuminous aliments;* the brain, nerves, eggs, &c.
9. *Fibrinous aliments;* comprehending the flesh and blood of different animals.

To these proximate principles *gluten* may be added, which has been termed the most animalized of vegetable principles. According to Dr. Prout,[5] it is separable into two portions, analogous to gelatin and albumen. It is very generally met with, although only in small pro-

[1] Carpenter, Principles of Human Physiology, p. 69, Amer. edit., Philad., 1855.
[2] Rudolph Wagner's Lehrbuch der Speciellen Physiologie, u. s. w. von D. Otto Funke. 1ste Lieferung, S. 181, Leipz., 1854.
[3] Précis, &c., ii. 34.
[4] A Treatise on Diet, 3d edit., p. 182, Lond., 1837; and art. Dietetics, in Cyclopædia of Practical Medicine, Amer. edit., Philad., 1845.
[5] Chemistry, Meteorology, and the Function of Digestion, (Bridgewater Treatise,) Amer. edit., p. 558, Philad., 1834.

portion, in the vegetable kingdom;—in all the farinaceous seeds, in the leaves of cabbage, cress, &c.; in certain fruits, flowers, and roots, and in the green fecula of vegetables in general; but it is especially abundant in wheat, and imparts to wheaten flour the property of fermenting and making bread. Of the nutritious properties of gluten, distinct from other principles, we know nothing precise: the superior nutritious powers of wheaten flour over those of all other farinaceous substances sufficiently attest, that, in combination with starch, it is highly nutritive.

Dr. Prout[1] arranges alimentary principles in four great divisions—the *aqueous*, *saccharine*, *oleaginous*, and *albuminous*. This has been taken as the basis for a classification by Dr. Pereira,[2] who admits twelve divisions:—the *aqueous*, *mucilaginous* or *gummy*, *saccharine*, *amylaceous*, *ligneous*, *pectinaceous*, *acidulous*, *alcoholic*, *oily* or *fatty*, *proteinaceous*, *gelatinous*, and *saline*. By the combination of these *alimentary principles* and *simple aliments*, our ordinary articles of food or *compound aliments* are formed. In this classification, the proteinaceous and gelatinous aliments are separated. The following simple arrangement is, perhaps, as little liable to objection as any:—

I. *Nitrogenized aliments*, (Albuminous of Prout.)	Fibrinous (Glutinous.) Albuminous. Caseinous. Gelatinous.
II. *Non-nitrogenized aliments*,	Amylaceous. Saccharine. Oleaginous.

The second division might be still farther simplified; for amylaceous aliments are convertible into sugar during the digestive process; and of both—as has been seen,—oleaginous matter may be formed.

Milk, furnished by the parent for the use of its offspring, contains an admixture of nitrogenized and non-nitrogenized aliments, which, as remarked by Dr. Prout,[3] is the true type of all food; and the same may be said of flour. It is interesting, indeed, to compare the ingredients which enter into the composition of milk, wheaten flour, and blood, as given by Dr. Robert Dundas Thomson[4]:—

Milk.	Flour.	Blood.
Curd or Casein,	Fibrin, Albumen, Casein, Gluten,	Fibrin, Albumen, Casein, Colouring matter.
Butter,	Oil,	Fat.
Sugar,	Sugar, starch,	Sugar.
Chloride of potassium, Chloride of sodium, Phosphate of soda, Phosphate of lime, Phosphate of magnesia, Phosphate of iron,	Ditto,	Ditto.

[1] On the Nature and Treatment of Stomach and Renal Diseases, Amer. edit., from the 4th revised London edit., ii. 354, Philad., 1843.

[2] A Treatise on Food and Diet, Amer. edit. by Dr. C. A. Lee, p. 38, New York, 1843.

[3] Op. cit., p. 362; and Chemistry, Meteorology, and the Function of Digestion, &c., Amer. edit., p. 259, Philad., 1834.

[4] Experimental Researches on the Food of Animals, &c., Amer. edit., p. 43, New York, 1846.

Water forms the basis of all drinks; but it frequently contains in addition other substances. These have been classed as follows:—1. *Water*, of different kinds. 2. *Vegetable and animal juices and infusions*, as lemon-juice, orange-juice, whey, tea, coffee, &c. 3. *Fermented liquors*, as wines, beer, cider, perry, &c.; and 4. *Alcoholic liquors*, as brandy, alcohol, kirsch-wasser, rum, gin, whisky, arrack, &c. &c. Dr. Pereira[1] has proposed the following more complete classification:—1. *Mucilaginous, farinaceous* or *saccharine drinks.* 2. *Aromatic* or *astringent drinks.* 3. *Acidulous* drinks. 4. Animal broths, or drinks containing *gelatin* and *osmazome.* 5. *Emulsive* or *milky* drinks; and 6. *Alcoholic* and other *intoxicating* drinks. Water—as has been seen—is considered by him amongst the alimentary principles.

An inquiry into the different properties of these various liquids does not belong to the physiologist. It may be remarked, however, that the arguments regarding the *natural* have been extended to this variety of aliments; and it has been contended, that water is "the most natural drink;" and that all others, which are the products of art, ought to be avoided. The remarks, already made on this subject, are sufficient. Water was, doubtless, at one period, the only beverage of man, as nakedness, the use of raw aliment, and the most profound ignorance of the universe, were his original condition; but no one will be presumptuous enough to declare, that he ought to continue naked, abjure cookery, and be plunged into his primitive darkness, on the plea that all these changes are so many artificial sophistications.[2] Water is, unquestionably, sufficient for all his wants; but the moderate use of fermented liquors, even if habitual, except in particular constitutions, is devoid, we think, of every noxious result. They are grateful; and many of them are even directly nutritious from the undecomposed sugar and mucilage which they contain. For this reason beer has been termed, not inaptly, "liquid bread."[3] With regard to distilled spirits, no evil would result from their total rejection from the table. Although they may, by their action on the digestive organs, be indirect means of nutrition, they contain no alimentary principle. They are received into the vessels of the stomach by imbibition; and always produce undue stimulation, when taken to any amount. This may be productive of little or no mischief, provided they be only used occasionally; but, if taken habitually and freely, serious visceral disorder may sooner or later ensue.

Lastly.—There are certain substances called *condiments* employed in diet, not simply because they are nutritive,—for many of them possess no such properties,—but because, when taken with food capable of nourishing, they promote its digestion, correct some injurious property, or add to its sapidity. Dr. Paris has divided these into *saline*, *spicy* or *aromatic*, and *oily.* It may be remarked, however, that certain articles are called, at times, *aliments;* at others, *condiments*, according as they constitute the basis or the accessory to any dish;—such are cream, butter, mushrooms, olives, &c. The advantage of condiments in animal

[1] Op. cit., p. 189.

[2] See an article by the author in the American Quarterly Review, ii. 422, Philad., 1827; and Fletcher, op. citat., p. 121.

[3] Kitchener, Invalid's Oracle, Amer. edit., p. 136, New York, 1831.

digestion is exemplified by many cases. The bitter principle, which exists in grasses and other plants, appears to be essential to the digestion of the herbivora,—acting as a natural stimulant; and it has been found that cattle do not thrive upon grasses which are destitute of it. Of the value of salt to the digestive function of his cattle, the agriculturist has ample experience; and the salt licks of our country show how grateful this natural stimulant is to the beasts of the forests. Charcoal, administered with fat,—as is done, in rural economy for fattening poultry, in many parts of England,—exhibits the advantage of administering a condiment; the charcoal of itself contains no nourishment, but it puts the digestive function in a condition for separating more nutritious matter from the food taken in, than it could otherwise do. A similar effect is produced by the plan,—adopted for the same purpose in certain parts of Great Britain,—of cramming the animal with walnuts, coarsely bruised, with the shell. This is asserted, by many rural economists, to be the most effectual plan for fattening poultry speedily; the coarse shell, in passing along the mucous membrane of the intestines, seems to stimulate it to augmented action, and a more bountiful separation of nutritious matter is the consequence. The aromatic condiments act in a similar manner.

In regard to the quantity of food required for human sustenance, nothing definite can be laid down. It must differ according to habit, constitution, way of life, age, sex, &c. The diet scale of the British navy affords a good average for the adult male in busy life, who requires more aliment than those in less active employment. It consists of from 31 to 35½ ounces of dry nutritious matter daily; of which 26 ounces are vegetable and the rest animal,—9½ ounces of salt meat, or 4½ ounces of fresh, being the proportion of the latter. This is found to be an ample allowance. That of the navy of the United States consists, four days in the week, of about 45 ounces; of which about 29 ounces are vegetable, and the rest animal,—the other three days, of about 40 ounces, of which about 24 ounces are vegetable,[1]—the vegetable matters consisting of beans or peas, biscuit, pickles, cranberries, sugar, tea, flour, dried fruit, and rice, an admixture of nitrogenized and non-nitrogenized articles, which, under ordinary circumstances, is amply sufficient for full nutrition; for, true scurvy appears to be caused by a deficient supply not only of nitrogenized food, but of the organic acids or salts of fresh vegetables; and one of the best of these, although not the most palatable, is the raw potato.[2]

In prisons a reduction must be made. In a convict ship, which took out 433 prisoners to New Holland, in 1802, the mortality was trifling, and the general health good, although the prisoners were allowed only 16 ounces of vegetable food, and 7½ ounces of animal food per day. Whenever the allowance is more restricted, or a due admixture of animal and vegetable food is not permitted, the health suffers, and signs of scorbutus appear;—a result occasionally witnessed in our public eleemosynary institutions, when under the care of ignorant and too

[1] The author's Dict. of Med. Science, art. Diet, 12th edit., p. 293, Philad., 1855.

[2] See a good article on the causation of scurvy in the British and Foreign Medico-Chirurgical Review, IV., 439, Lond., 1848.

economical superintendents. It would seem, from the experiments of M. Chossat, that under such circumstances an incapability is induced of digesting even the inadequate amount supplied.

The smallest quantity of food upon which life is known to have been actively supported was in the case of Cornaro, who affirms that he took no more than 12 ounces a day, and that chiefly vegetable, for a period of sixty-eight years. Of the amount that can be eaten by the glutton, we have surprising instances on record,—the stomach acquiring, at times, an enormous capacity. Captain Parry relates the case of a young Esquimaux, who was permitted to devour as much as he chose. It amounted, in the twenty-four hours, to thirty-five pounds of various kinds of aliment, including tallow candles; and a case has been published of a Hindoo, who could eat a whole sheep at a time.

These few remarks on the food of man will serve as an introduction to the mode in which the various digestive processes are accomplished. The more intimate consideration of alimentary substances, with their comparative digestibility, &c., will be found in another work of the author, to which the reader is referred.[1]

3. PHYSIOLOGY OF DIGESTION.

The detail entered into regarding the various organs concerned in digestion will have led to the anticipation, that the history of the function must be multiple and complex. The food is not, in the case of the animal—as it is in that of the vegetable—placed in immediate contact with the being to be nourished; an act of volition is, consequently, necessary to procure and to convey it to the upper orifice of the digestive tube. This act of volition is excited by an internal sensation —that of hunger—which indicates the necessity for taking fresh nourishment into the system. The appetite and hunger, with the prehension or reception of food, must therefore be regarded as part of the digestive operations. These may be enumerated and investigated in the following order:—1st. *Hunger*, or the sensation that excites us to take food. 2dly. *Prehension of food*, the voluntary muscular action, that introduces it into the mouth. 3rdly. *Oral* or *buccal digestion*, comprising the changes wrought on the food in the mouth. 4thly. *Deglutition*, or the part taken by the pharynx and œsophagus in digestion. 5thly. *Chymification*, or the action of the stomach on the food. 6thly. The *action of the small intestine*. 7thly. The *action of the large intestine*. And, 8thly. *Defecation* or *the expulsion of the fæces*. All these processes are not equally concerned in the formation of chyle. It is separated in the small intestine: the first six, therefore, belong to it;—the remainder relate only to the excrementitious part of the food. The digestion of solid food requires all the eight processes: that of liquids is more simple; comprising only thirst, prehension, deglutition, the action of the stomach, and that of the small intestine. Fluid rarely reaches the large intestine.

In inquiring into this important and interesting function, we shall first attend to the digestion of solids, and afterwards to that of liquids.

[1] Human Health, p. 179, Philad., 1844. For different dietaries, &c., see Pereira, Treatise on Food and Diet, Amer. edit., by Dr. C. A. Lee, p. 222, New York, 1843; and Art. Diet Scale, in the author's Med. Dictionary, 7th edit., Philad., 1848.

4. DIGESTION OF SOLID FOOD.

a. *Hunger.*

Hunger is an internal sensation, the seat of which is invariably referred to the stomach. Like every internal sensation, it proceeds from changes in the very texture of the organ. It is not produced by any external cause; and to it are applicable all those observations, that are elsewhere made on internal sensations in general. In its slightest condition, it is merely an *appetite* (ορεξις; Germ. Esslust); but if this be not heeded, the painful sensation of *hunger* (*Fames*, λιμος), supervenes, which becomes more and more acute and lacerating unless food is taken. If this be the case, however, the uneasiness gradually abates; and if sufficient be eaten, a feeling of satiety is produced. The sensation usually occurs, in the healthy state, after the stomach has been for some time empty, having finished the digestion of substances taken in at the previous meal. Habit has a great effect in regulating this recurrence; the appetite always appearing about the time at which the stomach has been accustomed to receive food. This artificial desire may be checked by various causes;—by the exciting or depressing passions, the sight of a disgusting object, or any thing that occasions intense mental emotion; or it may be appeased by filling the stomach with substances that contain no nutritious properties. As, however, the feeling of true hunger arises from the wants of the system, the natural and instinctive sensation soon appears, and cannot be long postponed by any of these means. Hence, it has been proposed to make a distinction between *appetite* and *hunger;* applying the former term to the artificial, the latter to the natural, desire. In these respects, there is certainly a wide distinction between them, as well as in the capriciousness, which occasionally characterizes the former, and gives rise to singular and fantastic preferences.

The sensation of hunger varies in intensity according to different circumstances. It is more powerful in the child and youth than in one who has attained his full height. In the period of second childhood, it is urgent,—probably owing to the diminished power of assimilation requiring that more aliment should be received into the stomach. In disease, the sensation is generally suppressed, and its place often supplied by loathing or disgust for food: at times, again, its intensity makes it a phenomenon of disease, as in bulimia, and pica; in the latter of which, the appetite is, at times, irresistibly directed to substances, which the person never before relished, or are not edible,—as chalk, earth, slate-pencil, &c., a prominent symptom of chlorotic and African cachexia. The appetite is also modified by exercise or inactivity, and other circumstances, extrinsic and intrinsic,—regular exercise, and the exhilarating passions; a cold and dry atmosphere, &c., augmenting it, whilst it is blunted by opposite circumstances. Long continued exertion, with a scanty supply of nourishment, if not continued so long as to injure the tone of the stomach, produces, occasionally, in adults, a voracious appetite and rapid digestion. Mr. Hunter has quoted, in illustration of this point, the following extract from Admiral Byron's narrative. After describing the privations he had suffered when shipwrecked on the coast of South America, the Admiral incidentally refers to their effect upon his appetite. "The governor ordered a table to be spread for us with cold ham and fowls, which only we three sat down to, and in a short time despatched more than ten men with common appetites would have done. It is amazing, that our eating to that excess we had done from the time we first came among these kind Indians had not killed us, as we were never satisfied, and used to take all opportunities for some months after, of filling our pockets, when we were not seen, that we might get up two or three times in the night to cram ourselves."[1]

Authors have distinguished the local from the general phenomena of hunger; but many of their assertions on these points appear imaginative. We are told by M. Adelon[2] and others,[3] that the stomach becomes contracted, and that this change is effected by the action of its muscular coat alone;—the mucous or lining membrane becoming wrinkled, and the peritoneal coat, externally, permitting the organ to retire between its laminæ. Such, MM. Tiedemann and Gmelin[4] assert, is the result of their observations. M. Magendie,[5] however, affirms, that after twenty-four, forty-eight, and even sixty hours complete abstinence, he has never witnessed this contraction of the organ. It had always considerable dimension, especially in its splenic portion; and not until after the fourth or fifth day did it appear to him to close upon itself, diminish greatly in capacity, and slightly change its position; and these effects were not observed unless the fasting was rigorously maintained.

At the time that the stomach changes its shape and situation, the duodenum is said to be drawn slightly towards it; its parietes appear thicker,—and the mucous follicles and nervous papillæ project more into the interior. Its cavity is void of food, and contains only a little saliva, mixed with bubbles of air; a small quantity of mucus; and, according to some, a little bile and pancreatic juice, which the traction of the duodenum has caused to flow into it.

Much dispute has arisen as to whether the circulation of the blood in the stomach experiences any mutation. M. Dumas[6] was of opinion, that when the organ is empty, it receives less blood than when full; either on account of the great flexion of the vessels in the former case, or on account of the compression experienced by the nerves in consequence of the contracted state of the organ. He thinks that, under such circumstances, a part of the blood sent to it reflows into the liver, spleen, and omentum; and he regards these organs as diverticula for the blood of the stomach, especially as the liver and spleen are then less compressed, and the omentum is more extensive, owing to the retraction of the stomach. Bichat, however, denies both the fact and its explanation. He affirms, that on opening animals suffering under hunger, he never observed the vessels of the stomach less full of blood, the mucous membrane less florid, or the vessels of the omentum more

[1] Byron's Voyage, p. 181; and Hunter on the Animal Economy, p. 196.
[2] Physiologie de l'Homme, ii. 396.
[3] Rullier, Art. Faim, in Dict. de Médecine, tom. viii., Paris, 1823.
[4] Die Verdauung nach Versuchen, u. s. w.; or French translation, by A. J. L. Jourdan, Paris, 1827.
[5] Op. citat., ii. 25.
[6] Principes de Physiologie, Paris, 1806.

turgid. Is it not true, he adds, that the vessels of the stomach are more flexuous when the organ is empty; being, as well as the nerves, connected with the serous coat, they are unaffected by changes of size in the organ; and besides, the retraction of the stomach could never be great enough to compress the nerves. He denies, moreover, that the liver and spleen are more free, and the omentum larger, whilst the stomach is empty, as the abdominal parietes contract in the same proportion as the stomach. Magendie,[1] however, contests this last assertion of Bichat; and affirms, on the faith of positive experiments, that the pressure sustained by the abdominal viscera is in a ratio with the distension of the stomach. If the stomach be full, the finger, introduced into the cavity of the abdomen through an incision in its parietes, will be strongly pressed upon, and the viscera forced towards the opening; whilst, if it be empty, the pressure as well as the tendency of the viscera to escape through the opening is considerable. During the state of vacuity of the organ, he remarked that the different reservoirs in the cavity of the abdomen,—the bladder and gall bladder,—were more easily filled by their proper fluids. With regard to the quantity of blood circulating through the stomach in the empty and full state,—he is disposed to believe, that the organ receives less in the former condition; but that in this respect it does not differ from other abdominal viscera.

The *general* effects, said to be produced by hunger, in contradistinction to the *local*, are;—debility and diminished action of every organ; the circulation and respiration are less frequent; the heat of the body sinks; the secretions diminish, and all the functions are exerted with more difficulty, if we except absorption, which it is affirmed, and with much probability, is augmented. If the abstinence be so long protracted as to cause death, the debility of the functions becomes real, and not sympathetic. Respiration and circulation languish; all the animal functions totter; whilst absorption continues, and the blood is supplied by the decomposition of the different organs,—the fat, the various liquid matters and the tissues of the organs being successively subjected to its action. It is obvious, however, that, with the drain perpetually taking place, this state of affairs cannot exist long; the blood becomes diminished in quantity, and insufficient in every respect to vivify the organs; the functions of the brain are perverted, and, in many instances, furious delirium has closed the scene; whilst, at others, the miserable sufferer has sunk passively into the sleep of death. Occasionally, again, so dreadfully painful are the sensations caused by protracted privation of food, that the most violent antipathies and dearest affections have been overcome; and numerous instances have occurred in which the sufferer has attacked his own species, friends, children, and even his own person. The horrible picture of the shipwreck, by Byron,[2] is not a mere romance. It is a narrative of facts that have actually occurred, expanded somewhat by the imagination of the poet.

Dr. James Currie[3] has related the case of a person, who died of

[1] Précis, &c., edit. cit., ii. 26. [2] Don Juan, canto ii. 58.
[3] Medical Reports, &c., Amer. edit., Philad., 1808.

inanition from stricture of the œsophagus, the particulars of which may exemplify the phenomena presented by some of those who perish from abstinence. The records of such cases are rare. From the 17th of October to the 6th of December, the patient was supported, without the aid of the stomach, by means of broth clysters; and was immersed in a bath of milk and water. At one period he had a parched mouth: a blister discharged only a thin, coagulable lymph; and the urine was scanty, extremely high-colored, and intolerably pungent. The heat of the body was natural and nearly uniform from first to last; and the pulse was perfectly natural until the last days. His sleep was sound and refreshing; spirits even; and intellect unimpaired, until the last four days of existence, when clysters were no longer retained. Vision was deranged on the first of December, and delirium followed on the succeeding day; yet the eye was unusually sensible, and the sense of touch remarkably acute. The surface and extremities were at times of a burning heat; at others, clammy and cold. On the fourth, the pulse became feeble and irregular, and respiration laborious; and, in ninety-six hours after all means of nutrition as well as medicine had been abandoned, he ceased to breathe. He was never much troubled by hunger. Thirst was, at first, troublesome, but it was relieved by the tepid bath. This was a case in which the patient sank tranquilly to death. In others, the distressing accompaniments above described are met with; and the death is that of a furious maniac.

The period at which the fatal event may occur from protracted abstinence is dependent on many circumstances. As a general rule the young and robust will expire sooner than the older; and this will have to be our guidance in questions of survivorship, where several individuals have perished together from this cause. The picture, drawn by Dante of the sufferings and death of Count Ugolino della Gherardescha, who saw his sons successively expire before him from hunger, is in this respect true to nature.

> "Now when our fourth sad morning was renew'd,
> Gaddo fell at my feet, outstretch'd and cold,
> Crying:—'Wilt thou not, father! give me food?'
> There did he die; and as thine eyes behold
> Me now, so saw I three fall, one by one,
> On the fifth day and sixth; whence in that hold,
> I, now grown blind, over each lifeless son
> Stretch'd forth mine arms. Three days I called their names,
> Then Fast achieved what Grief not yet had done."
>
> "INFERNO," canto xxxiii.

In some experiments on inanition undertaken by M. Chossat,[1] on pigeons and turtle doves, the following general phenomena were observed. Commonly, the animal remained calm during the first half or two-thirds of the period. It then became more or less agitated, and this state continued as long as the temperature remained elevated. On the last day of life, however, the restlessness ceased, and gave place to stupor. When set at liberty, it sometimes looked round with astonishment, without attempting to fly, and at times closed its eyes, as if in a state of sleep. Gradually, the extremities became cold, and

[1] Recherches Expérimentales sur l'Inanition, Paris, 1843; noticed in Brit. and For. Med. Rev., April, 1844, p. 347.

the limbs so weak as to be no longer able to sustain it in the standing posture. It fell over on one side, and remained in any position in which it might be placed, without attempting to move. Respiration became slower and slower; the general weakness increased, and the insensibility became more profound; the pupils dilated; and life became extinct,—at times in a calm and tranquil manner; at others, after convulsive actions, producing opisthotonic rigidity of the body.

He tried to discover the effect of age in modifying the continuance of life during inanition, but was unable to ascertain the relative ages of the turtle doves, the subjects of his experiments; he endeavoured, however, to form some estimate—although, obviously, a fallacious one—from their relative weights, classing them as "young," "middle-aged," or "adult," according as their weights were beneath 120 grammes, from 120 to 160, or above 160. The following table is interesting, however, by showing the duration of life, and the loss of substance during inanition, in animals of different weights.

	WEIGHT OF THE BODY.		LOSS OF THE BODY.			
	Weight at commencement.	Weight at death.	Entire absolute loss.	Proportional loss in 1000 parts.	Daily proportional loss.	Duration of life.
	Gram.	Gram.	Gram.			
a. Young . . .	110·42	82·84	27·58	0·250	0·081	3·07
b. Middle-aged	143·62	91·60	52·02	0·362	0·059	6·12
c. Old	189·36	101·61	87·75	0·463	0·035	13·36

The entire absolute loss, and the proportionate loss, were much greater in the heavier animals; the daily loss was by much the most rapid in the lightest; and it is probable, that this was owing to the more rapid waste which takes place in the young.

The sensation of hunger resembles every other sensation in the mode in which it is accomplished. There must be impression, conduction, and perception. That the encephalon is the organ of the last part of the process is proved by all the arguments used in the case of the internal sensations in general. Without its intervention in this, as in every other case, no sensation can be accomplished. The stomach is the organ in which the impression is effected; and by means of the nerves this impression is conveyed to the spinal marrow and encephalon. The eighth pair or pneumogastric nerves have generally been regarded as the agents of this transmission; and it has been affirmed by Baglivi, Valsalva, Haller, Dumas, Legallois, Chaussier, and others, that if they be divided in the neck, although the stomach may be favourably circumstanced, in other respects, for the developement of the impression of hunger, and the encephalon for its reception, there is no sensation; but MM. Leuret and Lassaigne,[1] Dr. John Reid,[2] Nasse,[3] and Longet,[4] deny, that such effect follows the division of these

[1] Recherches Physiologiques et Chimiques pour servir à l'Histoire de la Digestion, Paris, 1825.

[2] Edinb. Med. and Surg. Journal, April, 1839, and art. Par Vagum, in Cyclop. of Anat. and Physiol., Pt. xxviii. p. 899, Lond., April, 1847.

[3] Untersuchungen zur Physiologie und Pathologie, Bonn, 1835–6.

[4] Traité de Physiologie, ii. 342, Paris, 1850.

nerves; and the first gentlemen affirm, that horses have eaten as usual, and apparently with the same appetite, after they had removed several inches of the pneumogastric nerves; and even continued to eat after the stomach was filled. To these experiments we shall have occasion to refer hereafter. They by no means, however, exhibit that this internal sensation differs in its essence from others.

A difficulty, which the physiologist has always felt, concerns the precise nature of the action of impression. Its seat is clearly in the stomach. This was shown incontestably by a case of fistulous opening into the organ, which fell under the care of Dr. Beaumont, and to which there will be frequent occasion to refer. When the subject of this case was made to fast until his appetite was urgent, it was immediately assuaged by feeding him through the aperture. To the stomach, indeed, all our feelings refer the sensation. It is dependent upon some modification occurring in the very tissue of the viscus; and in the nerves, which, as has been shown, are the sole agents in all phenomena of sensibility. These nerves are spread over the stomach, so that the precise seat of the impression cannot be as accurately defined as in the case of the organs of external sense. Moreover, the nerves of the stomach proceed from two essentially different sources,—the eighth pair, and great sympathetic. The question consequently arises:—on which of these is the impression made? The results of the experiment of cutting the eighth pair in the neck would appear to decide in favour of the former.

As to the proximate or efficient cause of hunger, we cannot expect to arrive at any satisfactory conclusion. It is a sensation; and, like all sensations, inscrutable.[1] Theories, however, as on all obscure topics, have been numerous, and these have generally been of a mechanical or a chemical nature. Some have attributed it to the mechanical friction of the parietes of the stomach against each other, in consequence of its contraction; in which state, they affirm, the mucous coat is rugous, and its papillæ and follicles prominent. It is manifest, however, from the structure of the organ, that no such friction can take place. Yet this view was embraced by Haller.[2] Dr. Fletcher[3] ascribes it to a kind of permanent though partial contraction of the muscular fibres of the stomach;—"not that alternate general contraction and relaxation, which produces a sensible motion of this organ, nor that permanent general contraction, which would serve to diminish its cavity, but that kind of permanent contraction, which takes place in certain fibres alone, and perhaps through a part of their length only, and by which these fibres are, as it were, drawn away from the others, or, in other words, a minor degree of cramp." Others, again, have accounted for the sensation by the action of the gastric juice, which is supposed to have a tendency to irritate the internal membrane. In proof of this, they refer to a case, mentioned by Mr. Hunter, in which the mucous membrane, in a man who died of fasting, was found corroded. The gastric juice is, however, incapable of eroding

[1] J. Béclard, Traité élémentaire de Physiologie, p. 26, Paris, 1855.
[2] Element. Physiol., lib. xix., sect. 2, § 12, Bern., 1764.
[3] Rudiments of Physiology, Part iii., by Dr. Lewins, p. 73, Edinb., 1837.

living animal matter; and the numerous cases, which have occurred since that of Hunter, have shown, that the corrosion and perforation, which we meet with on dissection, may be referred to an action after death, and be totally unconnected with the sensation felt during life. We have, indeed, no reason for believing, that the gastric juice can ever attain a state of acridity, and affect physically the surface by which it is secreted. It has been remarked, that it is a law of the animal economy, that no secretion acts upon the part over which it is destined to pass, provided such part be in a healthy condition. Yet Sömmering[1] ascribes the pain from long-continued fasting to the action of the gastric juice; and Dr. Wilson Philip[2] is manifestly induced to believe that its influence on the stomach is, in some mode or other, productive of the sensation: his remarks, however, tend simply to show,—what we have so many opportunities for observing, that the sensation can be postponed by exciting vomiting, or inducing, for the time, a morbid condition of the stomach.

The unanswerable objection to all these views is the fact—repeatedly proved by Dr. Beaumont,[3] and which the author had an opportunity of observing—that, in the fasting state there is little or no gastric juice in the cavity of the stomach. Dr. Beaumont thinks, that the sensation of hunger is produced by distension of the vessels, that secrete the solvent; but such distension, if it exist—which is by no means proved—must itself be consecutive on the nervous condition that engenders the sensation: the efficient cause of such condition has still to be explained.

Bichat, again, attributed it to the lassitude or fatigue of the stomach, occasioned by the contraction of its muscular coat when continued beyond a certain time. In answer to this, it may be remarked, that if any thing impedes the nutrition of the body, hunger continues, although the stomach may be distended. This happens in cases of scirrhous pylorus, where the nutritive mass cannot pass into the small intestine, to be subjected to the action of the chyliferous vessels, and the losses of the body cannot, therefore, be repaired;—facts which would seem to show, that hunger is a sensation excited in the stomach by sympathy with the wants of the constitution; and that it is immediately produced by some inappreciable alteration in the condition of the nerves of the organ. It appears, from the experiments of M. Magendie,[4] that when the cerebrum and a great part of the cerebellum were removed in ducks, the instinct of seeking food was lost in every instance, and the instinct of deglutition in many: food, however, introduced into the stomach, was found to be digested.

b. *Prehension of Food.*

The arms and mouth have been described as organs of prehension. It is scarcely necessary to say, that the hands seize the food and convey it to the mouth under ordinary circumstances; but there are cases in

[1] De Corp. Human. Fabric., tom. vi., Traject. ad Mœnum, 1794–1801.
[2] Experimental Inquiry into the Laws of the Vital Functions, 2d edit., Lond., 1818.
[3] Experiments and Observations on the Gastric Juice, and the Physiology of Digestion, p. 57, Plattsburg, 1833.
[4] Précis, &c., ii. 168.

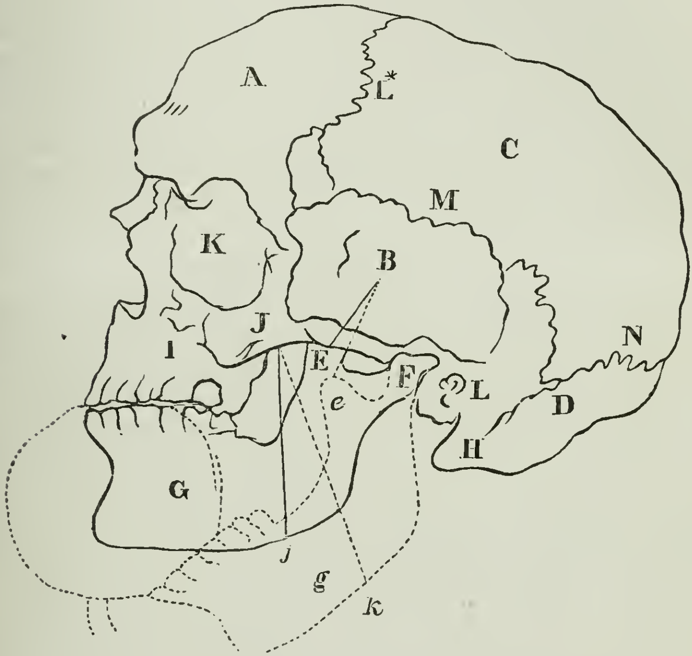
which the mouth is the sole or chief organ of prehension. Most animals are compelled to use the mouth only. When the food is conveyed to it by the hands, it must open to receive it. The mode in which this is effected has given rise to controversy; and, strange to say, is not yet considered determined. Whilst some physiologists have asserted, that the lower jaw alone acts in opening the mouth moderately; others have affirmed, that both the jaws separate a little;—the lower, however, moving five or six times as much as the upper. That the latter is the correct view can be proved by positive experiment. If, when the mouth is closed, we place the flat side of the blade of a knife against the teeth of both jaws; and, holding the knife immovably, separate the jaws; we find, that both jaws move on the blade; but the lower to a much greater extent than the upper. Now, as the upper jaw is fixed immovably to the head, the whole head must, of necessity, participate in this movement; and the question arises, what are the agents that produce it? Some attribute it to a slight action of the extensor muscles of the head; and affirm, that whilst the depressors of the lower jaw carry it downwards, the extensors of the head draw the head slightly backwards, and thus raise the upper jaw.

MM. Magendie[1] and Adelon[2] assert, that when the mouth is opened moderately, the upper jaw does not participate; but, that if the motion be "forced" or extensive, it participates slightly. The experiment, however, with the knife, which is adduced by M. Adelon himself, completely overthrows this notion; and shows, that both jaws act, whenever the mouth is slightly opened. M. Magendie agrees with those who consider, that, whenever the upper jaw is raised, it must be by the head being thrown back on the vertebral column; and he properly remarks, that where there is a physical impediment to the depression of the lower jaw, the mouth must be opened solely by the retroversion of the head on the spine. M. Ferrein[3] conceived, that the motion of the upper jaw is occasioned by the action of the stylo-hyoideus muscle, and the posterior belly of the digastricus; and he affirms, that whilst the anterior fasciculus or belly of the digastricus depresses the lower jaw; the posterior belly with the stylo-hyoideus carries the head backwards, and, with it, the upper jaw. The attachments, however, of these muscles sufficiently show, that they cannot be the agents: the mastoid process, to which the posterior belly of the digastric muscle is attached, is near the articulation of the head with the atlas; whilst the styloid process, to which the stylo-hyoideus is attached, is anterior to the articulation; and its effect ought to be to depress the upper jaw. The view of Professor Chaussier is the most probable. He ascribes the slight elevation of the upper jaw to the mechanical arrangement of the joint of the lower. The temporo-maxillary articulation is not formed by a single condyle, but by two, which are so disposed, that the lower cannot roll downwards during the depression of the lower jaw without causing the upper condyle to roll upwards, and, consequently, to elevate slightly the upper jaw. Under ordinary circumstances, then, the jaws cannot be at all separated without both participating; but if we determine to fix the upper jaw, we can make the lower the sole agent in the movement.

[1] Op. citat., ii. 43. [2] Op. citat., ii. 408.
[3] Mémoir. de l'Acad. des Sciences pour 1744.

As soon as the food is introduced into the mouth, the jaws are closed to retain it, and subject it to mastication. Frequently, however, they assist in the act of prehension, as when we bite a fruit, to separate a portion from it; the incisor teeth acting, in such case, like scissors. This is chiefly produced by the contraction of the muscles that raise the lower jaw; and it is probable, that the action of the stylo-hyoideus

Fig. 52.



Action of the Lower Jaw in Prehension.

A. Frontal bone. B. Temporal. C. Parietal. D. Occipital. E. Coronoid process of the lower jaw, to which the temporal muscle is attached. F. Condyloid process or head of the lower jaw. G. Lower jaw. H. Mastoid process. I. Upper jaw. J. Cheek bone. K. Orbit. L. Meatus auditorius externus. L*. Coronal suture. M. Squamous suture. N. Lambdoidal suture. *g*. Lower jaw depressed.

is concerned in the movement; drawing the head and upper jaw with it downwards and forwards. The levator muscles of the jaw act here with great disadvantage;—the lower jaw representing a lever of the third kind; the fulcrum being in the joint; the power at the insertion of the levator muscles; and the resistance in the substance between the teeth. The arm of the resistance is, consequently, the whole length of the lever; and we can understand why we are capable of developing so much more force, when the resistance is placed between the molares; and why old people,—who have become toothless, and are, consequently, constrained to bite with the anterior part of the jaws,—the only portion that admits of contact,—cannot bite with any degree of strength.

The size of the body, put between the incisor teeth, influences the degree of force that can be brought to bear upon it. When small the force can be much greater, as the levator muscles are inserted perpendicularly to the lever to be moved, and the whole of their power is advantageously exerted; but if the body be so large, that it can scarcely be received into the mouth, and be resisting withal, the incisors can scarcely penetrate it;—the insertion of the levator muscles into the jaw being rendered very oblique; and the greater part of the force they develope consequently lost. This will be readily seen by Figure 52. When the mouth is closed, or nearly so, the masseter, and temporal muscles represented respectively by the lines B E and J *j*, are inserted nearer the perpendicular; but when the lower jaw is depressed, so that the situation of these muscles is represented by the dotted lines B *e* and J *k*, the direction in which the muscles act will be more oblique, and, therefore, more disadvantageous. When the muscles of the jaws are incapable, of themselves, of separating the substance, as in the case of the apple, the assistance of the muscles of the hand is invoked; whilst the muscles on the posterior part of the neck, which are inserted into the head, draw it backwards; and, by these combined efforts, the substance is forcibly divided.

c. *Oral or Buccal Digestion.*

The changes, effected upon the food in the mouth, are important preliminaries to the function that has to be executed in the stomach and duodenum. As soon as it enters the cavity, it is subjected to the action of the organ of taste, and its sapid qualities are appreciated. By its stay there, it also acquires nearly the temperature of the cavity. This is, however, a change of little moment, unless the food is so hot, that it would injure the stomach, if passed rapidly into it. Under such circumstances, it is tossed about in the mouth, until it has parted with its caloric to various portions of the parietes of the cavity; and then, if in a fit state for the action of deglutition, it is transmitted along the œsophagus; but the most important parts of oral digestion are the movements of mastication and insalivation by which solid food is comminuted, and imbued with the secretions poured into the interior of the mouth, and which we have shown to be of a very compound character.

Under the sense of taste, the influence of the agreeable or disagreeable character of the food upon the digestive function is expatiated upon. It is unnecessary, therefore, to do more than allude to the subject here. We find that whilst a luscious aliment excites to prolonged mastication, and the salivary glands to augmented secretion, the masticatory and salivary organs, by dividing and moistening the food, permit the organs of gustation to enjoy the savour by successive applications.

When the food is received into the mouth, if it be sufficiently soft, it is commonly swallowed immediately; unless the flavour is delicious, when it is detained. If solid, and, especially, if of any size or density, it is divided into separate portions, or chewed,—the action constituting *mastication.* If the consistence of the substance be moderate, the tongue, by being pressed strongly against the bony palate, is sufficient to effect this division; bruising it, and at the same time, expressing its fluid portions. If the consistence be greater, the action of the jaws and teeth is required. For this purpose, the lower jaw is successively depressed and elevated by the action of its depressors and levators;

and the horizontal or grinding motion is produced at pleasure by the action of the pterygoids. Whilst these muscles are acting, the tongue and cheeks are incessantly moving, so as to convey the food between the teeth, and insure its comminution. Mastication is chiefly effected by the molares. There is advantage in using them, independently of their form, in consequence of the arm of the resistance being much shortened, as has already been shown.

The teeth are well adapted for the service they have to perform. The incisors, as their name imports, are used for cutting; hence their coronæ come to an edge; the canine teeth penetrate and lacerate, and their coronæ are acuminated; whilst the molares bruise and grind, and their touching surfaces are tuberous. The first, having usually no great effort to sustain, are placed at the extremity of the lever; the latter, for opposite reasons, are nearest the fulcrum. To preclude displacement by the efforts they have occasionally to sustain, they are firmly fixed in the alveoli or sockets; and, as the roots are conical, and the alveoli accurately embrace them, the force, as in the case of the wedge, is transmitted in all directions, instead of bearing perpendicularly on the jaw, which it would do, were the fangs cylindrical. The molar teeth, having the greatest efforts to sustain, are furnished with several roots; or with one that is extremely large.

The gums add materially to the solidity of the junction of the teeth with the jaws. They are themselves formed of highly resisting materials, so as to withstand the pressure of hard and irregular substances. Whenever they become spongy, and fall away from the teeth, the latter become loose; and are frequently obliged to be extracted, in consequence of the loose tooth acting as an extraneous body, and inflaming the lining membrane of the alveolus. The arrangement of the jaw is well adapted to the function; the lower jaw passing behind the upper at its anterior part; but coming in close contact at the sides, where mastication is chiefly effected.

During the whole time that mastication is going on, the mouth is closed;—anteriorly, by the lips and teeth, which prevent the food from falling out of the cavity; and posteriorly by the velum palati, the anterior surface of which is applied to the base of the tongue. At the same time, the food is undergoing *insalivation* or admixture with the various fluids poured into the mouth, and particularly with the saliva, the secretion of which is augmented, not only by the presence of food, but even by the sight of it, especially if the food be desirable;—giving rise to what is called "mouth-watering." It is probable, that, independently of mental association, the action of the secretory organs is increased by the agitation of the organs themselves during the masticatory movements. It has, indeed, been asserted, that the parotid glands are so situate, as regards the jaws, that the movement of the lower jaw presses upon them, and forces out the saliva; but MM. Bordeu and J. Cloquet have demonstrated, anatomically and by experiment, that this is not the case.[1]

It has been supposed by some, that admixture with saliva communicates to the food its first degree of animalization; or in other words,

[1] Adelon, op. cit., ii. 418.

its first approximation to the substance of the animal it has to nourish. Such are the opinions of Professor Jackson[1] and M. Voisin.[2] The former asserts, that he has ascertained positively, that the saliva exerts a very energetic operation on the food, separating, by its solvent properties, some of its constituent principles, and performing a species of digestion. MM. Tiedemann and Gmelin, too, think that the water, and the carbonates and acetates of potassa and soda, and the chlorides of potassium and sodium, of the saliva, contribute to soften and dissolve the food; whilst the nitrogenized materials, the salivary and albuminous matters, communicate to it a first degree of animalization. It is more probable, however, that the main use of mastication and insalivation is to give the food the necessary consistence, in order that the stomach and small intestine may exert their action upon it in the most favourable manner; and that, consequently, the changes effected upon it in the mouth, are chiefly of a mechanical character. In the case of many substances—as sugar, salt, &c.—a true solution takes place in the saliva; and this probably happens to sapid bodies in general;—the particles being separated by imbibing the fluid. Krimer,[3] of Leipzig, held in his mouth a piece of ham, weighing a drachm, for three hours. At the expiration of this time, the ham was white on its surface, and had increased in weight twelve grains. He believes, that the tears assist in digestion, and that they flow constantly by the posterior nares into the stomach.

It would seem that an important action of the saliva is the conversion of starch—boiled starch—into dextrin or grape sugar. From one drachm of starch, Dr. Wright[4] obtained in twelve hours, at a temperature of 98°, by admixture with saliva, thirty-one grains of sugar. This probably takes place by the action of some nitrogenized secretion, like pepsin in stomachal digestion. It has been affirmed, indeed, on the strength of numerous and varied experiments detailed before the French Academy of Sciences,[5] by MM. Bernard de Villefranche and Barreswil, that in the gastric juice, pancreatic fluid, and saliva, an organic principle or ferment exists, which is common to them all; and that it is the nature of the chemical reaction associated with it, which alone determines their power of digesting the different alimentary principles. In an alkaline fluid, all three have the power of transforming starch, and do not digest meat; whilst in an acid fluid they dissolve meat, but do not act on starch. Hence, they think, it appears easy to transform these fluids into each other, and to make for example an artificial gastric juice from pancreatic fluid. The action of saliva, however, is said to be less energetic, both on meat and starch, than the pancreatic fluid. For the organic compound in the saliva, M. Mialhe[6] proposes the name *animal diastase* or *diastase salivaire*. It would seem, however, from the experiments of MM. Magendie[7] and

[1] Principles of Medicine, p. 354, Philad., 1832.
[2] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.
[3] Versuch einer Physiologie des Blutes, Leipz., 1820.
[4] Lond. Lancet, 1841–2.
[5] Comptes Rendus, 7 Juillet, 1845.
[6] Lancette Française, Avril, 1845; and Mialhe, Chimie appliquée à la Physiologie et à la Thérapeutique, p. 39, Paris, 1856.
[7] Comptes Rendus, 1847, p. 117.

Bernard,[1] that many substances besides saliva,—as pieces of the mucous membrane of the mouth, bladder, rectum, and other parts, various animal and vegetable tissues, and even morbid products effect the transformation of starch into sugar; but that the gastric fluid does not. The part of the saliva, according to M. Bernard, which appears to be most active in this transformation, is that secreted by the small glands and the mucous membrane of the mouth;[2] but it has been properly observed, by Messrs. Kirkes and Paget,[3] that if the influence of saliva in aiding the digestion of farinaceous food be admitted, we have yet to seek for the corresponding purpose served by the saliva of the carnivora, which consume no such food; and on this point we possess at present no information.

M. Bernard[4] believes, that the parotid, labial and buccal glands, which secrete a more watery fluid, are aquiparous; and more especially auxiliaries in mastication; whilst the maxillary, sublingual and palatal are muciparous, and furnish the thicker mucous matter which surrounds the alimentary bolus, and facilitates its onward course in the act of deglutition.[5] The secretion from the different glands certainly varies greatly. M. Lassaigne[6] examined the fluid from the parotid and the submaxillary in the same animal. The latter was much more viscid, and resembled mucus in consistence.

It is probable that the main action of saliva is to soften the food; for when substances are well mixed with water, they are retained in the mouth for a short time only; and, consequently, in an amylaceous solution there is no opportunity for change to be effected. Experiments, instituted by M. Lassaigne,[7] by a committee of the Institute, and by M. Bernard[8] show, that when the food is dry a considerable admixture of saliva takes place, whilst if it be so softened, that mastication is not needed, it absorbs scarcely any. In executing these experiments, the aliment was weighed before giving it to the animal; the œsophagus was cut across; and the aliment, after having been chewed and insalivated, was received through the wound in the neck. The difference in weight indicated the quantity of saliva that had been added to it. According to Professor Bérard,[9] these experiments teach us: *First.* That dry forage absorbs about four or five times its weight of saliva and mucus. *Secondly.* That dry feculaceous articles (oats, starch and barley meal) absorb a little more than their weight. *Thirdly.* That green forage (green leaves and stalks of barley) absorb a little less than half their weight; and *fourthly;* that moist feculaceous articles (starch and bran) to which sufficient water has been added for the

[1] Canstatt und Eisenmann, Jahresbericht über die Fortschritte in der Biologie, im Jahre, 1847, s. 117.

[2] See, also, Frerichs, in Canstatt's Jahresbericht, 1850, p. 134; and art. Verdauung, in Wagner's Handwört. der Physiologie, Bd. iii. Abth. 1, Braunsch., 1846; and Bidder und Schmidt, Die Verdauungssäfte, s. 1, Mitau und Leipz., 1852.

[3] Manual of Physiology, 2d Amer. edit., p. 163, Philad., 1853.

[4] Comptes Rendus, 1852, p. 236.

[5] Béraud, Manuel de Physiologie, p. 88, Paris, 1853.

[6] Journ. de Chimie Méd., p. 393; and Scherer, in Canstatt's Jahresbericht, 1852, s. 106.

[7] Journal de Chimie Médicale, p. 472, Paris, 1845.

[8] Archives Générales de Médecine, 4e s rie, tom. xiii. p. 1.

[9] Cours de Physiologie, p. 721, Paris, 1848.

food to be swallowed without previous mastication, do not sensibly absorb any.

Both mastication and insalivation are of moment, in order that digestion shall be accomplished in perfection; and, accordingly, they who swallow food without due mastication, or waste the saliva by constant and profuse spitting, are more liable to attacks of dyspepsia, or imperfect digestion. It is proper, however, to add, that Dr. Budge,[1] on extirpating the salivary glands in animals, did not find that they sustained the smallest apparent injury; whence he conjectures, that certain glands can act as succedanea to others, and that on the removal of the salivary glands the pancreas supplies perhaps the fluid usually secreted by the other.

A table given by Dr. Robert Dundas Thomson[2] as the results of experiments on two cows, signally exhibits the beneficial effects of a proper grinding of the food. The cows were fed on entire barley and malt steeped in hot water. They were then fed on crushed barley and malt prepared in the same manner. The influence of the finer division of the grain in increasing the quantity of milk is strikingly shown.

	Brown Cow. Milk in periods of five days.	White Cow. Milk in periods of five days.
Entire barley and grass,	111½ lbs.	106 lbs.
	97⅕ "	94 "
Entire malt and grass,	96 "	98 "
	95 "	104 "
Crushed barley, grass and hay,	115½ "	109½ "
	105 "	109⅓ "
	110 "	110 "
Crushed malt and hay,	97 "	106½ "
	96 "	107½ "
	98 "	111½ "

The table exhibits, that with the entire barley, the milk diminished during the second five days of the experiment, whilst with the crushed barley it had a tendency to increase during each succeeding period.

The degree of resistance, and sapidity of the food, apprise us when mastication and insalivation have been sufficiently exerted. When this is the case it is subjected to the next of the digestive processes. Some physiologists have affirmed, that the uvula is the organ which judges when the food is adapted for deglutition. M. Adelon, whose views are generally worthy of great favour and attention, asserts, "that it judges by its mode of sensibility, of the degree in which the aliment has been prepared in the mouth; of the extent to which it has been chewed, impregnated with saliva, and reduced to paste; and, according to the impression it receives, it excites, sympathetically, the action of all those parts; directs the convulsive contraction of the muscles that raise the pharynx: even keeps the stomach on the alert, and disposes it to receive favourably or to reject the food passing to it." Such a function would be anomalous. It is, indeed, inconceivable that so insignificant an organ could be possessed of those elevated attributes. Observation, also, proves, that the notion is the offspring of fancy. M. Magendie[3]

[1] Medicinische Zeitung, May 4, 1842; cited in British and For. Med. Rev., July, 1842, p. 221.

[2] Experimental Researches on the Food of Animals, Amer. edit., New York, 1846.

[3] Op. cit., ii. 58.

asserts, that he has known several persons who had entirely lost the uvula, either by venereal ulceration or by excision, and yet he never remarked that their mastication experienced the slightest modification, or that they swallowed inopportunely. Our experience corresponds with that of M. Magendie. We know of more than one individual in whom there is not the slightest vestige of uvula; yet they taste, chew, and swallow like other persons.

d. *Deglutition.*

The act of swallowing, although executed with extreme rapidity, and apparently simple, is the most complicated of the digestive operations, and requires the action of mouth, pharynx and œsophagus. It has been well analyzed by M. Magendie,—first of all in a thesis, maintained at the *École de Médecine* of Paris, in 1808, and subsequently, in his *Précis Élémentaire de Physiologie.*[1] To facilitate its study, he divides it into three stages. In the *first*, the food passes from the mouth into the pharynx; in the *second*, it clears the apertures of the glottis and nasal fossæ, and attains the œsophagus; and, in the *third*, it clears the œsophagus and enters the stomach.

1. When the food has been sufficiently masticated and imbued with saliva, it is collected by the action of the cheeks and tongue upon the upper surface of the last organ;—the mass being more or less rounded, and hence usually termed *alimentary bolus.* Mastication now stops; the tongue is raised and applied against the bony palate in succession from the tip to the root, and the alimentary bolus, having no other way of escaping from the force pressing it, is directed towards the pharynx. Previous to this, the pendulous veil of the palate had been applied to the base of the tongue. The bolus now raises it to the horizontal position: the circumflexus palati muscles render the velum tense, so that the food cannot pass into the nasal fossæ; and the muscles that constitute the pillars of the fauces—palato-pharyngei and glosso-staphylini—contribute to this effect. By this combination of results, the food is impelled into the pharynx. The muscles, which, by their action, apply the tongue to the roof of the mouth and to the velum palati, are the proper muscles of the organ, aided by the mylo-hyoidei. In this first stage of deglutition, the motions are voluntary, except those of the velum palati. The process is not executed with rapidity, and is easily intelligible. Such is not the case with the second stage. The actions in it are complicated, and executed with so much celerity, that they have been regarded as a kind of convulsion.

2. The distance over which the bolus has to travel, in the second stage, is trivial; the rapidity of its course is owing to the larynx or superior aperture of the windpipe, which opens into the pharynx having to be cleared instantaneously, otherwise respiration might be arrested, and serious effects ensue. The mode, in which the second stage is accomplished, is as follows. As soon as the alimentary bolus comes in contact with the pharynx all is activity; the pharynx contracts, embraces, and presses the bolus; and the velum pendulum, drawn down by the palato-pharyngei and glosso-staphylini muscles,

[1] Edit. cit., ii. 63.

fulfils a similar office. At the same time, the genio-glossus, by applying the tongue to the palate, from the tip to the roof, raises the os hyoides, the larynx, and, with it, the anterior paries of the pharynx. The same effect is directly induced by the contraction of the mylo-hyoidei, and genio-hyoidei muscles; which, instead of acting as depressors of the lower jaw, as they do during mastication, take the jaw as their fixed point, and are levators of the os hyoides. The larynx is thus elevated, carried forwards, and meets the bôlus to render its passage over the aperture of the larynx shorter, and, therefore, more speedy. To aid this effect,—when we make great efforts to swallow, the head is inclined forwards on the thorax. Whilst the os hyoides and the larynx are raised, they approach each other,—the upper margin of the thyroid cartilage passing behind the body of the hyoid bone: the epiglottic gland is pushed backward, and the epiglottis is depressed, and inclined backwards and downwards, so as to cover the entrance to the larynx. The cricoid cartilage executes a rotatory motion on the inferior cornua of the thyroid cartilage, which occasions the entrance of the larynx to become oblique from above to below, and, of course, from before to behind. The bolus thus glides over its surface; and, forced on by the veil of the palate, and by the constrictors of the pharynx, reaches the œsophagus.

At one time, it was universally believed, that the epiglottis is the sole agent in preventing substances from passing into the larynx. The experiments of M. Magendie[1] have, however, demonstrated, that this is the combined effect of the motions of the larynx just described, and of the muscles, whose office it is to close the glottis; so that, if the laryngeal and recurrent nerves be divided in an animal, and the epiglottis be left in a state of integrity, deglutition is rendered extremely difficult;—the principal cause, that prevented the introduction of aliments into the glottis, having been removed by the section. M. Magendie, and MM. Trousseau and Belloc[2] refer to cases of individuals, who were totally devoid of epiglottis, and yet swallowed without any difficulty,[3] and Magendie remarks, that if, in laryngeal phthisis with destruction of the epiglottis, deglutition be laboriously and imperfectly accomplished, it is owing to the carious condition of the arytenoid cartilages, and to the lips of the glottis being so much ulcerated as not to be able to close the glottis accurately. Whilst the bolus, then, is passing over the top of the larynx, respiration must be momentarily suspended, owing to closure of the glottis; and if, from distraction of any kind, we attempt to speak, laugh, or breathe, at the moment of deglutition, the glottis opens, the food enters, and cough is excited, which is not appeased until the cause is removed. This is what is called, in common language, "the food going the wrong way." As soon as the bolus has cleared the glottis, the larynx descends, the epiglottis rises, and the glottis opens to give passage to the air. This is

[1] Mémoire sur l'Usage de l'Épiglotte dans la Deglutition, Paris, 1813; and Précis, &c., i. 67.

[2] A Practical Treatise on Laryngeal Phthisis, &c. &c.; Dr. Warder's translation, p. 84, in Dunglison's American Medical Library, Philad., 1839.

[3] A similar case is given by Targioni, in which neither deglutition nor speech was impaired; Morgagni, xxviii. 13.

owing to the relaxation of the muscles that had previously raised the larynx, and closed the glottis. M. Chaussier thinks, that the sterno-hyoidei muscles now act, and aid in producing the descent of the parts.[1] The author had an excellent opportunity for noticing the laryngeal phenomena of deglutition in a man, who had cut his throat, and in whom a fistulous opening remained, which permitted the inferior ligaments of the larynx to be seen distinctly. The glottis was observed to be firmly closed.[2] M. Longet,[3] who has made experiments connected with this subject on animals, is disposed to think, that the displacements of the base of the tongue and epiglottis are the two most important conditions, and that the closed glottis is only the last obstacle set up against the passage of food into the larynx; but he evidently assigns too much importance to the epiglottis.

The velum pendulum, then, protects the posterior nares and the orifices of the Eustachian tube from the entrance of the food; and the epiglottis, the elevation of the larynx, with the contraction of the muscles that close the glottis, are the great agents in preventing it from passing into the larynx. The whole of this second stage consists of rapid movements, of an entirely involuntary character, which, according to Bellingeri,[4] are under the presidency of the palatine filaments of the fifth pair; but these filaments are sensory; the motor filaments being probably derived from the pneumogastric; or, according to M. Longet, from the spinal.[5]

3. In the third stage, the pharynx, by its contraction, forces the alimentary bolus into the œsophagus, so as to somewhat dilate the upper part of the organ. The upper circular fibres are thus excited to action, and force the food onward. In this way, by the successive contraction of the circular fibres, it reaches the stomach. In the upper part of the œsophagus, the relaxation of the circular fibres speedily follows their contraction; but this is not the case in the lowest third, the circular fibres remaining contracted, for some time after the entrance of the bolus into the stomach,—probably to prevent its return into the œsophagus. The passage of the bolus along the œsophagus is by no means rapid. M. Magendie[6] affirms, that he was struck, in the prosecution of his experiments, with the slowness of its progression. At times, it was two or three minutes before reaching the stomach; at others, it stopped repeatedly, and for some time. Occasionally, it even ascended from the inferior extremity of the œsophagus towards the neck, and subsequently descended again. When any obstacle existed to its entrance into the stomach, this movement was repeated a number of times, before the food was rejected. Every one must have felt the slowness of the progression of the food through the œsophagus when a rather larger morsel than usual has been swallowed. If it stops, we are in the habit of aiding its progress by drinking some fluid,

[1] Adelon, op. citat., ii. 424.

[2] Dunglison's American Medical Intelligencer, Oct., 1841, p. 73.

[3] L'Examinateur Médical, 17 Oct., 1841; and Brit. and For. Med. Rev., Jan., 1842, p. 228.

[4] Dissert. Inaugural., Turin, 1823; noticed in Edinb. Med. and Surg. Journ. for July, 1834.

[5] Traité de Physiologie, ii. 337, Paris, 1850.

[6] Op. citat., ii. 69.

or by swallowing a piece of bread. Occasionally, however, the probang is necessary to propel it. The pain produced in these cases, according to M. Magendie, is owing to the distension of the nervous filaments, that surround the pectoral portion of the canal. In the case of a female, labouring under a disease which permitted the interior of the stomach to be seen, M. Hallé noticed, that whenever a portion of food passed into the stomach, a sort of ring or *bourrelet* was formed at the cardiac orifice, owing to the mucous membrane of the œsophagus being forced into the stomach by the contraction of its circular fibres.[1] The mucous fluid, pressed out from the different follicles by the passage of the bolus, materially facilitates its progress.

Notwithstanding the facility with which deglutition is accomplished, almost every part of it is uninfluenced by volition, being dependent upon organization, and exerted instinctively. If the alimentary matter contained in the mouth be not sufficiently masticated; or if it has not the shape, consistence, and dimensions, it ought to possess; or if the ordinary movements, that precede mastication, have not been executed,—whatever effort we may make, deglutition is impracticable. We constantly meet with persons who are unable to swallow the smallest pill; and yet can swallow a much larger mass, if certain preliminary motions be executed, which, in the case of the pill, are inadmissible, in consequence of its being usually of a nauseous character. It appears, that the involuntary parts of the function are excited by the stimulation of the aliment; for, if we attempt to swallow the saliva several times in succession, we find after a time, that the act is impracticable, owing to the deficiency of saliva. Every one must have experienced the difficulty of deglutition, when the mouth and fauces were not duly moistened by their secretions. The involuntary part of deglutition is under the control of the reflex system of nerves. An impression is made by the alimentary matters upon the excitor or afferent nerves, which impression is conveyed to the gray matter of the spinal cord, and in the invertebrata to ganglia corresponding to it; whence it is reflected to the muscular fibres that have to be thrown into contraction. The portion of the spinal cord, which serves as a centre for the reception of the impression, and the point of departure for the motor influence, is the medulla oblongata; and the experiments of Dr. John Reid[2] lead to the inference, that the glosso-pharyngeal, which is chiefly distributed to the mucous surface of the tongue and fauces, is the excitor nerve; the pharyngeal branches of the pneumogastric, the motors. It would seem, however, that these nerves do not alone possess the function; for after they have been divided, the animal is still capable of imperfect deglutition. The associate excitor or afferent nerves, Dr. Reid concludes to be—the branches of the fifth pair, that are distributed to the fauces, and probably also those of the superior laryngeal distributed to the pharynx:—the associate motor or efferent nerves being branches of the hypoglossal, that are distributed to the muscles of the tongue, and to the sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles; filaments of the inferior laryngeal that ramify on the larynx; some of the branches of the fifth pair that supply the

[1] Op. cit., ii. 70. [2] Edinb. Med. and Surg. Journ., vol. xlix.

levator muscles of the lower jaw; the branches of the portio dura that ramify upon the digastric and stylo-hyoid muscles, and upon the muscles of the lower part of the face; and probably some of the branches of the cervical plexus, which unite themselves to the descendens noni. It must be admitted, however, that this part of the physiology of deglutition is obscure.[1]

Some individuals are capable of swallowing air; and, according to M. Magendie,[2] it is an art that can be attained by a little practice. He affirms it, indeed, to be a more common power than is usually supposed. In 100 students he has generally found eight or ten who possessed it. In the stomach, the air acquires the temperature of the viscus, becomes rarefied, and distends the organ; exciting, in some, a feeling of burning heat; in others, an inclination to vomit, or acute pain. He thinks it probable, that its chemical composition undergoes change; but, on this point, nothing certain is known. The time of its stay in the stomach is variable. Commonly, it ascends into the œsophagus, and makes its exit through the mouth or nostrils. At other times, it passes through the pylorus, and diffuses itself through the whole of the intestinal canal, as far as the anus,—distending the abdominal cavity, and simulating tympanites. M. Magendie refers to the case of a young conscript, who feigned the disease in this manner.

e. *Chymification.*

When the food has experienced changes impressed upon it by the preceding process, it reaches the cavity of the stomach, where it is retained for several hours, and undergoes another portion of the digestive action, being converted into a pultaceous mass, to which the term *chyme* has been applied; whilst the process has been called *chymification.* It does not seem, that all physiologists have employed these terms in this signification; some have confounded *chyle* with *chyme;* and *chylification* with *chymification.* The former of these processes is distinctly an intestinal act: the latter is exclusively gastric.

The aliment, as it is sent down by repeated efforts of deglutition, descends into the splenic portion of the stomach without difficulty, as regards the first mouthfuls. The stomach is but little compressed by the surrounding viscera, and its parietes readily separate to receive the food; but when it is taken in considerable quantity, the distension gradually becomes more difficult, owing to the compression of the viscera and the distension of the abdominal parietes. The accumulation takes place chiefly in the splenic and middle portions. Dr. Beaumont[3] observed, that when a piece of food was received into the stomach, the rugæ of the latter gently closed upon it; and if it were sufficiently fluid, gradually diffused it through the cavity of the organ, but entirely excluded more whilst the action continued. The contraction ceasing, another quantity of food was received in the same manner. It was found, in the subject of his experiments, that when the valvular portion of the stomach, situate at the fistulous aperture, was depressed, and

[1] Longet, Traité de Physiologie, ii. 334, 337, Paris, 1850.
[2] Op. cit., ii. 146.
[3] Experiments, &c., on the Gastric Juice, p. 110.

solid food introduced, either in large pieces or finely divided, the same gentle contraction or grasping motion took place, and continued for fifty or eighty seconds, and it would not allow of another quantity, until that period had elapsed: the valve could then be depressed, and more food put in. When the man was so placed, that the cardia could be seen, and was permitted to swallow a mouthful of food, the same contraction of the stomach and grasping of the bolus were invariably observed to commence at the œsophageal ring. Hence, when food is swallowed too rapidly, irregular contractions of the muscular fibres of the œsophagus and stomach are produced; the vermicular motions of the rugæ are disturbed, and the regular process of digestion is interrupted.

Whilst the stomach is undergoing distension by food, it experiences changes in its size, situation, and connexion with the neighbouring organs. The dilatation does not affect its three coats equally. The two laminæ of the peritoneal coat separate, and permit the stomach to pass farther between them. The muscular coat experiences a true distension; its fibres lengthen, but still so as to preserve the particular shape of the organ; whilst the mucous coat yields, in those parts especially where the rugæ are numerous; that is, along the great curvature and splenic portion. In place, too, of being flattened at its anterior and posterior surfaces, and occupying only the epigastrium, and a part of the left hypochondrium, it assumes a rounded figure. Its great *cul-de-sac* descends into the left hypochondre and almost fills it, and the greater curvature descends towards the umbilicus, especially on the left side. The pylorus preserves its position and connexion with the surrounding parts;—being fixed down by a fold of the peritoneum. It is chiefly forwards, upwards, and to the left side, that the dilatation occurs. The posterior surface cannot dilate on account of the resistance of the vertebral column, and of a ligamentous formation which prevents the stomach from pressing on the great vessels behind it. Its cardiac and pyloric portions are also fixed; so that when it is undergoing distension, a movement of rotation takes place, by which the great curvature is directed slightly forwards; the posterior surface inclined downwards, and the superior upwards. A wound received in the epigastric region, will, consequently, penetrate the stomach in a very different part, according as the viscus may be, at the time, full or empty.

The dilatation of the organ produces changes in the condition of the abdomen and its viscera. The total size of the abdominal cavity is augmented; the belly becomes prominent; and the abdominal viscera are compressed,—sometimes so much as to excite a desire to evacuate the contents of the bladder or rectum. The diaphragm is crowded towards the thorax, and is depressed with difficulty; so that, not only is ordinary respiration cramped; but speaking and singing become laborious. When the distension of the organ is pushed to an enormous extent, the parietes of the abdomen may be painfully distended, and the respiration really difficult. It is in these cases of over-distension, that an energetic contraction of the œsophagus is necessary; hence the advantage of the strong muscular arrangement at its lower part. In proportion as the food accumulates in the stomach, the sensation of hunger diminishes; and if we go on swallowing additional portions, it entirely disappears, or is succeeded by nausea and loathing. The quantity, necessary to produce this effect, varies according to the individual, as well as to the character of the food; a very luscious article sooner cloying than one that is less so. A due supply of liquid with solid aliment also enables us to prolong the repast with satisfaction.

As the stomach, when distended, presses upon the different viscera and upon the abdominal parietes, it is obvious, that it must experience a proportionate reaction. An interesting question consequently arises;—to determine the causes, which oppose the passage of the food back along the œsophagus, as well as through the pylorus. M. Magendie[1] found, in his vivisections, that the lower portion of the œsophagus experiences, continuously, an alternate motion of contraction and relaxation. The contraction begins at the junction of the two upper thirds with the lowest third; and is propagated, with some rapidity, to the termination of the œsophagus in the stomach. Its duration, when once excited, is variable; the average being, at least, half a minute. When thus contracted, it is hard and elastic, like a cord strongly stretched. The relaxation, that succeeds the contraction, occurs suddenly and simultaneously in all the contracted fibres; at times, however, it appears to take place from the upper fibres towards the lower. In the state of relaxation, the œsophagus is remarkably flaccid;—forming a singular contrast with that of contraction. This movement of the œsophagus is, according to M. Magendie,[2] under the dependence of the eighth pair of nerves. When these nerves were divided in an animal, the œsophagus was no longer contracted. Still it was not relaxed. Its fibres, deprived of nervous influence, were shortened with a certain degree of force; and the canal remained in a state intermediate between contraction and relaxation.

The lower part of the œsophagus of the horse, for an extent of eight or ten inches, is not contractile in the manner of muscles. M. Magendie[3] found, when the eighth pair of nerves was irritated, or the parts were exposed to the galvanic stimulus, that no contraction was produced. The œsophagus of that animal is, however, highly elastic; and its lower extremity is kept so strongly closed, that for a long time after death, it is difficult to introduce the finger; and considerable pressure is required to force air into it. M. Magendie considers this arrangement to be the true reason, why horses vomit with such difficulty as to occasionally rupture the stomach by their efforts. The alternate motions of the œsophagus, which we have described, oppose the return of the food from the stomach. The more the organ is distended, the more intense and prolonged is the contraction, and the shorter the relaxation. The contraction commonly coincides with inspiration; the time at which the stomach is, of course, most strongly compressed. The relaxation is synchronous with expiration.

The pylorus prevents the alimentary mass from passing into the duodenum. In living animals, whether the stomach be filled or empty, this aperture is constantly closed by the constriction of its fibrous ring, and the contraction of its circular fibres; and, so accurately is it closed,

[1] Précis, &c., ii. 82. [2] Ibid., ii. 18. [3] Ibid., ii. 19.

that if air be forced into the stomach from the œsophagus, the organ must be distended, and considerable exertion made to overcome the resistance of the pylorus. Yet, if air be forced from the small intestine in the direction of the stomach, the pylorus offers no resistance;—suffering it to enter the organ under the slightest pressure;—a circumstance that accounts for the facility with which bile enters the stomach; especially when there exists inverted action of the duodenum. To the pylorus, however, a more active part has been assigned in the passage of the chyme from the stomach into the intestine. "Nothing in the animal economy," says Dr. Southwood Smith,[1] "is more curious and wonderful than the action of that class of organs of which the pylorus affords a remarkable example. If a portion of undigested food present itself at this door of the stomach, it is not only not permitted to pass, but the door is closed against it with additional firmness; or, in other words, the muscular fibres of the pylorus, instead of relaxing, contract with more than ordinary force. In certain cases, where the digestion is morbidly slow, or where very indigestible food has been taken, the mass is carried to the pylorus before it has been duly acted upon by the gastric juice: then, instead of inducing the pylorus to relax, in order to allow of its transmission to the duodenum, it causes it to contract with so much violence as to produce pain, while the food, thus retained in the stomach longer than natural, disorders the organ: and if digestion cannot ultimately be performed, that disorder goes on increasing until vomiting is excited, by which means the load that oppressed it is expelled.

"The pylorus is a guardian placed between the first and the second stomach, in order to prevent any substance from passing from the former until it is in a condition to be acted upon by the latter; and so faithfully does this guardian perform its office, that it often, as we have seen, forces the stomach to reject the offending matter by vomiting, rather than allow it to pass in an unfit state; whereas, when chyme, duly prepared, presents itself, it readily opens a passage for it into the duodenum." This view of the functions of the pylorus has antiquity in its favour. It is, indeed, as old as the name, which was given to it in consequence of its being believed to be a faithful porter or janitor (πυλωρος, "a porter"); but it is doubtless largely hypothetical. We constantly see substances traverse the whole extent of the intestinal canal, without having experienced the slightest change in the stomach. Buttons, half-pence, &c., have made their way through, without difficulty; as well as the tubes and globes, employed in the experiments of Spallanzani, Stevens, and others. There are certain parts of fruits, which are never digested, yet the "janitor" is always accommodating. Castor oil is capable of being wholly converted into chyle; and would be so, if it could be retained in the stomach and small intestines; yet there is no agent, which arrests its onward progress. Still, from these, and other circumstances, M. Broussais[2] has inferred, that there is an internal gastric sense, which exerts an elective agency; detaining, as a general rule, substances that are nutritive; but suffering others to pass.

[1] Animal Physiology, Library of Useful Knowledge, p. 41.

[2] Traité de Physiol. appliquée à la Pathologie; translated by Drs. Bell and La Roche, p. 314, Philad., 1832.

The presence of food in the stomach after a meal soon excites the organ to action, although no change in the food is perceptible for some time. The mucous membrane becomes more florid, in consequence of the larger afflux of blood; and the different secretions appear to take place in greater abundance; become mixed with the food, and exert an active and important part in the changes it experiences in the stomach. Direct experiment has proved that such augmented secretion actually occurs. If an animal be kept fasting for some time, and then be made to swallow dry food, or even stones, and be deprived of liquid aliment, the substances swallowed will be found,—on killing it some time afterwards,—surrounded by a considerable quantity of fluid. Such is not the case with animals killed after fasting. The stomach then contains no fluid matter. The augmented secretion in the former case must, therefore, be owing to the presence of dry food in the stomach. That it is not simply the fluid passed down by deglutition,—the salivary and mucous secretions, for example,—is proved by the fact, that the same thing occurs when the œsophagus has been tied. Besides, if the stomach of a living animal be opened, and any stimulating substance be applied to its inner surface, a secretion is seen to issue in considerable quantity at the points of contact; and, again, if an animal be made to swallow small pieces of sponge, attached to a thread hanging out of the mouth, by means of which they can be withdrawn, they become filled with the fluids secreted by the stomach, and, on withdrawing them, a sufficient quantity can be obtained for analysis. Such experiments have been repeatedly performed by MM. Réaumur,[1] Spallanzani,[2] and others. In Dr. Beaumont's case[3] the collection of gastric secretion was obtained by inserting an elastic gum tube through the opening: in a short time fluid enough was secreted to flow through the tube. This admixture with the fluids of the mucous membrane of the stomach, and the secretions continually sent down from the mouth by the efforts of deglutition, is the only apparent change witnessed for some time after the reception of solid food. Sooner or later, according to circumstances, the pyloric portion of the organ contracts, sending into the splenic portion the food it contains: to the contraction dilatation succeeds; and this alternation of movements goes on during the whole of digestion. After this time chyme only is found in the pyloric portion mixed with a small quantity of unaltered food. This motion of contraction and relaxation has been called *peristole;* and it appears, at first, to be limited to the pyloric portion, but gradually extends to the body and splenic portion, so that, ultimately, the whole stomach participates in it. It consists in an alternate contraction and relaxation of the circular fibres; and the gentle oscillation, thus produced, not only facilitates the admixture of the food with the gastric secretions, but continually exposes fresh portions to their action. The experiments of Bichat satisfied him, that the peristole is more marked, the greater the fulness of the stomach. He made dogs swallow forced-meat balls, in the centre of which he placed cartilage, and found, that when the stomach was greatly charged, the cartilages were pressed out of the balls. This did not happen, when the organ contained a smaller quantity of food.

[1] Mémoir. de l'Acad. pour 1752. [2] Expér. sur la Digestion, Genève, 1783.
[3] Experiments, &c., on the Gastric Juice, p. 106.

The ordinary course and direction of the revolutions of the food, according to Dr. Beaumont,[1] are as follows:—The bolus, as it enters the cardia, turns to the left; passes the aperture; descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns in the course of the lesser curvature, and makes its appearance again at the aperture in its descent into the great curvature to perform similar revolutions. That these are the revolutions of the contents of the stomach, he ascertained by identifying particular portions of food; and by the fact, that when the bulb of the thermometer was introduced during chymification, the stem invariably indicated the same movements. Each revolution is completed in from one to three minutes, and the motions are slower at first than when chymification has made considerable progress. In addition to these movements, the stomach is subjected to more or less succussion from the neighbouring organs. At each inspiration it is pressed upon by the diaphragm; and the large arterial trunks in its vicinity, as well as the arteries distributed over it, subject it to constant agitation.

It has been already remarked, that the *peristaltic* or *vermicular action*—*peristole*—of the stomach,—and the action extends likewise to the intestines,—is effected by the muscular coat of the organ. It is, however, an involuntary contraction, and appears to be little influenced by the nervous system; continuing, for instance, after the division of the eighth pair of nerves; becoming more active, according to M. Magendie,[2] as animals are more debilitated, and even at death; and persisting after the alimentary canal has been removed from the body. MM. Tiedemann and Gmelin,[3] however, affirm, that by irritating the plexus of the eighth pair of nerves situate around the œsophagus with the point of a scalpel, or touching it with alcohol, the peristole of both stomach and intestines can be constantly excited; and Valentin and Dr. John Reid state, that distinct movements may be excited in the stomach by irritating the pneumogastric. This involuntary function, as well as that exerted by the heart and other involuntary organs, affords us a striking instance of the little nervous influence, which seems to be requisite for carrying on many of those functions that have to be executed independently of volition through the whole course of existence; and which appear to be excited at times, in a reflex manner, by the presence of appropriate excitants;—of food, in the case of the peristaltic action of the stomach; of blood, in that of the heart, &c.; and yet may be carried on in the absence of all nervous influence, as in the cases of the intestinal canal, and the heart, which may contract for a long time after they have been removed from the body. In the intestinal canal, the movements are doubtless influenced by the spinal cord, probably through the sympathetic by means of the fibres which the canal derives from it: but although *influenced* by the spinal cord, they are not dependent upon it for contractility. As Dr. Carpenter has remarked, the canal is enabled to propel its contents by its inherent powers; but—as in other instances—the nervous centres exert a general control over even the organic functions, "doubtless for the purpose

[1] Op. citat., p. 110.
[2] Précis Élémentaire, ii. 20.
[3] Die Verdauung, u. s. w., or French edit., Recherches sur la Digestion, Paris, 1827.

of harmonizing them with each other, and with the conditions of the organs of animal life."[1]

The gentle, oscillatory or vermicular motion of the stomach, and the admixture with the fluids, secreted by its internal membrane, as well as by the different follicles, &c., in the supra-diaphragmatic portion of the alimentary canal, are probably the main agents in the digestion operated in the stomach.

Much contrariety of sentiment has existed regarding the precise organs that secrete the fluid which oozes out as soon as food is placed in contact with the mucous coat of the stomach. Whilst some believe it to be exhaled from that membrane; others conceive it to be secreted by the numerous follicles, seated in the membrane as well as in that of the lower portion of the œsophagus; or by what have been termed *gastric glands*. The analogy of many animals, especially of birds, would render the last opinion the most probable. In them we find, in the second stomach, the cardiac or gastric glands largely developed; and it is probable that they are the great agents of the secretion of the digestive fluid. (See Figs. 28 and 29.) MM. Tiedemann and Gmelin[2] affirm, that the more liquid portion of the gastric fluid is exhaled, and that the thicker, more ropy and mucous portion is secreted by the follicles. Rudolphi[3] assigns it a double origin;—from exhalants, and gastric glands; whilst MM. Leuret and Lassaigne[4] ascribe its formation exclusively to the villi. The views of Bernard and Kölliker have been given before.[5]

Dr. Beaumont,[6] who had an excellent opportunity for experimenting on this matter, remarks, that on applying aliment, or any irritant, to the internal coat of the stomach, and observing the effect through a magnifying-glass, innumerable minute, lucid points, and very fine papillæ, could be seen protruding, from which a pure, limpid, colourless, slightly viscid fluid distilled, which was invariably and distinctly acid. On applying the tongue to the mucous coat in its empty, unirritated state of the stomach, no acid taste could be perceived. Although no apertures were perceptible in the papillæ, even with the assistance of the best microscope that could be obtained, the points, whence the fluid issued, were clearly indicated by the gradual appearance of innumerable very fine, lucid specks, rising through the transparent mucous coat, and seeming to burst, and discharge themselves upon the very points of the papillæ, diffusing a limpid, thin fluid over the whole interior gastric surface.

A like difference of opinion has prevailed regarding the chemical character of the fluids; and this has partly arisen from the difficulty of obtaining them identical. The true fluid secreted by the gastric follicles or mucous membrane can never, of course, be obtained for examination in a state of purity. It must always be mixed not only with the other secretions of the stomach, but with all those transmitted to the organ, by the constant efforts of deglutition. It is, consequently, to this mixed fluid that the term *gastric juice* has really been applied;

[1] Human Physiology, p. 151, Lond., 1842. [2] Op. citat.
[3] Grundriss der Physiologie, 2ter Band, 2te Abtheilung, s. iii., Berlin, 1828.
[4] Recherches sur la Digestion, Paris, 1825. [5] Page 83. [6] Op. citat., p. 103.

although it is more especially appropriated to the particular fluid, presumed to be secreted by the stomach, and to be the great agent in digestion. To the nature of the gastric juice and its effects in the process of digestion, we shall have occasion to recur presently.

It is probably owing to the quantity of fluid secreted by the stomach, that it is so largely supplied with bloodvessels; and that the mucous membrane is more injected, during the presence of food in the organ. Experiments, by Sir Benjamin Brodie[1] and others, would seem to show, that the secretion is under the influence of the eighth pair of nerves. Having administered arsenic to different animals—on some of which he had divided these nerves,—he found, that, whilst the stomachs of those, in which the nerves were entire, contained a large quantity of a thin, mucous fluid; in those, whose nerves were divided, the organ was inflamed and dry. Leuret and Lassaigne,[2] however, affirm, that division of the nerves had no influence on the secretion. But more of this presently.

Before entering into the views of different physiologists on chymification,—in other words, into the theories of digestion,—it will be well to refer to the physical and chemical properties of the *chyme*. Whether the changes in the food be simply physical or chemical, or whether the first stage of animalization be effected within the stomach, will be a topic for future inquiry. Chyme is a soft, homogeneous substance, of grayish colour and acid taste. Such are its most common characters: it varies, however, according to the food taken, as may be observed, by feeding animals on different simple alimentary substances, and killing them during digestion. This difference in its properties accounts for the discrepancy observable in the accounts of writers. The change wrought on aliments is, doubtless, of a chemical nature; but the new play of affinities is controlled by circumstances inappreciable to us. In the case of a female patient at the hospital *La Charité*, of Paris, who had been gored by a bull, and had a fistulous opening in the stomach, the food, during its conversion into chyme, appeared to have acquired an increase of its gelatin; a greater proportion of chloride of sodium; phosphate of soda and phosphate of lime; and a substance, in appearance, fibrinous.[3]

It has been said, again, that the food becomes decarbonized and more nitrogenized; that the carbon which disappears is removed by the oxygen of the air swallowed with the food, or by that contained in the food itself; and that the nitrogen proceeds from the secretions of the stomach, or predominates simply because the food is decarbonized. M. Adelon[4] has properly remarked, that the fact and the explanation are here equally hypothetical. Generally, the chyme possesses acid properties. MM. de Montègre,[5] Magendie,[6] and Tiedemann and Gmelin,[7] always observed it to be so. Haller[8] and Marcet found it to be neither acid nor alkaline. In the chyme examined by the latter gentleman, he detected albumen, an animal matter, and some salts, differing, however,

[1] Philos. Trans. for 1814.

[2] Op. citat.

[3] Richerand's Nouveaux Élémens de Physiologie, édit. 13ème, par Bérard, aîné, p. 72, Bruxelles, 1837.

[4] Physiol. de l'Homme, &c., edit. cit., tom. ii.

[5] Expériences sur la Digestion, Paris, 1824.

[6] Op. citat., ii. p. 87.

[7] Op. cit.

[8] Element. Physiol., xix. 1.

slightly, according as it proceeded from animal or vegetable food. In the latter case, it afforded four times as much carbon as in the former, but less saline matter; and this consisted of lime and an alkaline chloride. MM. Leuret and Lassaigne[1] analyzed the chyme from the stomach of an epileptic, who died suddenly in a fit, five or six hours after having eaten. It was of a white, slightly-yellowish colour; and strong, disagreeable taste. On analysis, it afforded a free acid,—the lactic; a white, crystalline, slightly saccharine matter, analogous to the sugar of milk; albumen, soluble in water; a yellowish, fatty, acid matter, analogous to rancid butter; an animal matter, soluble in water, having all the properties of casein; and a little chloride of sodium, phosphate of soda, and much phosphate of lime. Dr. Prout[2] affirms, that a quantity of chlorohydric acid is present in the stomach during the process of digestion. He detected it in that of the rabbit, hare, horse, calf, and dog, and in the sour matter ejected by persons labouring under indigestion:—a fact which has been confirmed by Mr. Children. MM. Tiedemann and Gmelin, and Dr. Beaumont,[3] affirm, that the secretion of acid commences, as soon as the stomach receives the stimulus of a foreign body, and that it consists of chlorohydric and acetic acids. The experiments of these gentlemen were not confined to the chymous mass obtained from digestible food. They examined the fluids, secreted by the mucous membrane when indigestible substances were sent into the stomach, and the acid character was equally manifested. These experiments, consequently, remove an objection, made by Dr. Bostock,[4] regarding the detection of the chlorohydric acid by Dr. Prout;—that, as there did not appear to be any evidence of the existence of this acid before the introduction of food into the stomach, it might rather be inferred, that it is, in some way or other, developed during the process of digestion. In all Dr. Beaumont's experiments, the chyme was invariably and distinctly acid.

The principal theories on chymification have been the following:[5]—

1. *Coction*, or *elixation*.—This originated with Hippocrates, and was vaguely used by him to signify the maceration, and maturation experienced by the food in the stomach. The doctrine was embraced by Galen and others, who ascribed to the organ, an *attracting*, *retaining*, *concocting*, and *expelling* quality effected by heat.[6] In proof of this, they affirmed that the heat of the stomach is increased during chymification; that the process is more rapid in the warm, than cold-blooded animal; that it is aided by artificial heat, and continues even after death, if care be taken to keep up the heat of the body; that in the experiments on artificial digestion made by Spallanzani, heat was always necessary, and the greater the degree of heat the more easy and complete the digestion.

It is hardly necessary to say that the heat of the stomach is totally insufficient to excite any coction or ebullition in the physical sense of

[1] Recherches, &c., p. 114.

[2] Philos. Trans. for 1824; and Bridgewater Treatise on Chemistry, &c., Amer. edit., p. 268, Philad., 1834.

[3] On the Gastric Juice, &c., p. 105.

[4] Physiology, 3d edit., p. 569, Lond., 1836.

[5] For different theories, ancient and modern, on chymification, see Béraud, Manuel de Physiologie, p. 130, Paris, 1853.

[6] Boerhaav., Prælectiones Academ. Not. Adv., § 86, tom. i., Götting., 1740–1743.

the term, and this applies particularly to the cold-blooded animal, which must digest, if not with the same, with due, rapidity.

2. *Putrefaction.*—The next great hypothesis was that of *putrefaction*, which, we are informed by Celsus,[1] was embraced by Plistonicus, a disciple of Praxagoras of Cos, who flourished upwards of three hundred years before the birth of Christ. Of late, it has had no advocates, but appears to have been the view embraced by Cheselden.[2] The reasons, urged in favour of it, have been;—the putrescible character of the materials employed as food; the favourable circumstances of a heat of 98° or 100°, and of moisture; and, by some, the fœtor of the excrements. The objections are, 1. That when the contents of the stomach are rejected, during chymification, they exhibit no evidence of putridity. 2. That in all the experiments, which have been made on the comparative digestibility of different substances, when it has been necessary to kill the animals at different stages of the digestive process, there has not been the slightest sign of putrefaction. 3. That opportunities frequently occur for witnessing ravenous fishes and reptiles with an animal or portion of an animal,—too large to be entirely swallowed,—partly in the stomach, and the remainder in the gullet and mouth. In these cases, where the food has remained in this situation some days, the part contained in the throat has been found putrid, whilst that in the stomach has been entirely sweet; and lastly, in Spallanzani's and other experiments, to be detailed presently, it was found, when food, in a state of putridity, was taken into the stomach, or mixed with the gastric juice out of the stomach, that it recovered its sweetness. It has been already observed, that it is the custom, in some countries, to eat the *gibier* or *game* in a state of incipient putrefaction; yet the breath is not tainted by it.

3. *Trituration.*—The mathematical physiologists,—Borelli,[3] Hecquet,[4] Megallotti,[5] Pitcairne,[6] and others,—after the example of Erisistratus,[7] attempted to refer the whole process of digestion to *trituration*, imagining, that the food is subjected in the stomach to an action similar to that of the pestle and mortar of the apothecary, or of the millstone; and that the chyle is formed like an emulsion. The most plausible arguments, in favour of this view of the subject, are drawn from the presumed analogy of the granivorous bird, whose stomach is capable of exerting an astonishing degree of pressure on substances submitted to it. There is no analogy, however, between the human stomach, and the gizzard of birds. The latter is a masticatory organ, and therefore possessed of the surprising powers which we have elsewhere described; whilst mastication, in man, is accomplished by distinct organs. No comparison can be instituted between the gentle oscillatory motion of the stomach, and the forcible compression exerted by the digastric muscle of the gizzard. The simple introduction of the finger through a wound of the abdomen has shown, that the compression exerted by

[1] De Medicinâ, curâ E. Milligan, edit. 2da, p. 5, Edinb., 1831.
[2] Anatomy of the Human Body, &c., 8th edit., p. 155, Lond., 1763.
[3] De Motu Animalium; Addit. J. Bernouillii, M. D., Medit. Mathem. Muscul., Lugd. Bat., 1710.
[4] Traité de la Digestion, Paris, 1710.
[5] Haller, Elem. Physiol., xix. 5.
[6] Works, &c., Lond., 1715.
[7] Cels., loc. citat.

it on its contents is totally insufficient to bruise any resisting substance. Moreover, we constantly see fruits,—as raisins and currants,—passing through the whole intestinal canal unchanged; whilst worms remain in the stomach—reside there—unhurt; and, we shall see presently, that the experiments of Réaumur and Spallanzani proved most convincingly, that digestion is effected independently of all pressure. The futility, indeed, of this mode of viewing the subject is signally illustrated by the fact, that, whilst Pitcairne estimated the power of the muscular fibres of the stomach at 12,951 pounds, Hales[1] thought that twenty pounds would come nearer the truth; and Astruc[2] valued its compressive force at five ounces!

4. *Fermentation.*—The system of fermentation had many partisans; amongst whom may be mentioned Van Helmont,[3] Sylvius,[4] Willis,[5] Boyle,[6] Grew,[7] Charleton,[8] Lower,[9] Raspail,[10] &c. Digestion, in this view, was ascribed to the chemical reaction of the elements of the food during their stay in the stomach;—the action being excited by food that had already undergone digestion, or by a leaven secreted for the purpose by the stomach itself. In favour of this view, it was attempted to show, that air is constantly generated in the organ, and that an acid is always produced as the result of fermentation,—the formation of chyme being referred by the greater number of physiologists to the food undergoing the vinous and acetous fermentations. The objections to this doctrine of fermentation are;—that digestion ought to be totally independent of the stomach, except as regards temperature; and the food ought to be converted into chyme, exactly in the same manner,—if it were reduced to the same consistence, and placed in the same temperature,—out of the body; which is not found to be the case. Bones are speedily reduced to chyme in the stomach of the dog, although they would remain unchanged for weeks, in the same temperature, out of the body. The facts of the voracious fishes before mentioned likewise prove the insufficiency of the hypothesis; according to which, digestion ought to be accomplished as effectually in the œsophagus as in the stomach. Yet it is found that, whilst the portion in the stomach is digested, the other may be unaltered, or be putrid. The truth is;—in healthy digestion, fermentation, in the ordinary acceptation of the term, does not occur; and, whenever the elements of the food react upon each other, it is an evidence of imperfect digestion; hence, fermentation is one of the most common signs of dyspepsia.

5. *Chemical solution.*—The theory of chemical solution, proposed by Spallanzani,[11] and subjected to modifications, has met with more favour from physiologists than any of the others that have been mentioned, and may be regarded as established. According to that observer,

[1] Statical Essays, ii. 174, 4th edit., Lond., 1769.
[2] Traité de la Cause de la Digestion, &c., Toulouse, 1714; and Haller, loc. citat.
[3] Ortus Medicinæ, &c., Amstel., 1648.
[4] Opera, Genev., 1781.
[5] Diatribæ duæ Medico-Philosophicæ, &c., Lond., 1659.
[6] Works, vol. ii., Lond., 1772.
[7] Comp. Anat. of the Stomach, &c., Lond., 1681.
[8] Œcon. Anim. Exerc. 2.
[9] Tractatus de Corde, &c., Amstel., 1671.
[10] Chimie Organique, p. 356, Paris, 1833.
[11] Dissertations relative to the Natural History of Animals and Vegetables: sect. i., Lond., 1789.

chymification is owing to the solvent action of a fluid, secreted by the stomach, which accumulates in that viscus between meals and during hunger,[1] and acts as a true menstruum on the substances exposed to it. This fluid,—to which he gave the name *gastric juice*,—he affirmed to be peculiar in each animal, according to its kind of alimentation,—corresponding, as regards its energy, with the rest of the digestive apparatus, and differing in its source in the series of animals; in some, proceeding from the follicles of the œsophagus; in others from those of the stomach; but always identical in the same animal; generally transparent, yellowish; of a saline taste; bitter; slightly volatile; and stronger in animals with a membranous than in those with a muscular stomach, and than in ruminant animals. To obtain the juice, Spallanzani opened animals, after they had been made to fast for a time; and collected the juice that had accumulated in their stomachs; or he made them swallow tubes pierced with holes, and filled with small sponges. By withdrawing these tubes, by means of a thread attached to them and suffered to hang out of the mouth, and expressing the sponges, he obtained the fluid in quantity sufficient for examination. To determine whether this fluid, obtained from fasting animals, was destined to chymify the food, he tried the following experiments. He caused numerous animals to swallow tubes filled with food, but pierced with holes, so that the juices of the stomach might be able to get into their interior; and found that chymification was effected, when he had taken the precaution to chew the substances before they were put into the tubes, or to triturate them; and the process was always more readily accomplished, the more easy the access of the fluids. On repeating these experiments on animals of various kinds, with a muscular or membranous, and musculo-membranous stomach; on pullets, turkeys, ducks, pigeons, rooks, frogs, salamanders, eels, serpents, sheep, cats, &c., he obtained the same results; and hence he affirmed, that trituration cannot be the essence of chymification. Réaumur,[2]—originally a believer in the doctrine of trituration,—had previously arrived at the same conclusion, by experiments of a similar kind. Spallanzani next repeated those experiments upon himself. Having well chewed different articles of food, he enclosed them in wooden tubes pierced with holes, and swallowed them; but, as the tubes caused pain in the bowels, he substituted small bags of linen. The substances contained in bags were digested without the bags being torn; a fact, which proved, that digestion must have been accomplished by means of a fluid, that penetrated them. In 1777, Dr. Stevens[3] repeated these experiments. He made a person swallow balls of metal, filled with masticated food, and pierced with holes: when the balls were voided,—thirty-six or forty-eight hours afterwards,—they were entirely empty. Lastly.—Spallanzani was desirous of seeing whether this solvent juice could effect digestion out of the body. He put some well-masticated food in small glass tubes, and mixed gastric juice with it. These tubes he placed in his axilla, in order that they might be exposed to the same degree of heat as in the

[1] It has been already stated, that the experiments of Dr. Beaumont have satisfactorily proved that no such accumulation takes place during hunger.

[2] Mémoir. de l'Acad. pour 1752.

[3] De Alimentorum Concoctione, § 24.

stomach; and in the space of fifteen hours, or of two days,—more or less,—the substances appeared to be converted into chyme. In these experiments he found it important to employ gastric juice, that had not been previously used, and to have a sufficient quantity of it.

From all these experiments, Spallanzani conceived it to be demonstrated, that chymification is a true chemical solution; and he endeavoured to deduce from them the degree of digestibility of different alimentary substances. Similar experiments were instituted by Dr. Beaumont.[1] In all cases, solution occurred as perfectly in the *artificial* as in the *real* digestions, but they were longer in being accomplished, for reasons which appear sufficient to explain the difference. In the former, the gastric secretion is not continuous; the temperature cannot be as accurately maintained, and there is an absence of those gentle motions of the stomach, which are manifestly so useful in accomplishing real digestion.

With regard to the precise nature of the gastric juice of Spallanzani, we have already observed that great contrariety of sentiment has prevailed; and that, in ordinary cases, it is impracticable to procure it unmixed with the other secretions of the digestive mucous membrane. Spallanzani affirmed, that the only properties he detected in it, were,—a slightly salt, bitterish taste; it was neither acid nor alkaline. Gosse[2] found it vary according to the nature of the animal,—whether herbivorous or carnivorous;—and to be always acid in the former. Dumas[3] held the same sentiments, and maintained, from experiments on dogs, that it was acid or alkaline, according as the animal had fed on vegetable or animal diet. He declared it, moreover, to be mawkish, thick, and viscid. Viridet[4] and others affirmed that it was always acid. Mr. Hunter[5] was not inclined to suppose, that there is any acid in the gastric juice as a component or essential part of it, "although an acid is very commonly discovered even when no vegetable matter has been introduced into the stomach." Scopoli[6] analyzed the gastric juice of the rook, and found it to consist of water, gelatin, a saponaceous matter, muriate of ammonia, and phosphate of lime. Carminati[7] describes it as salt, bitter, and frequently acid; and MM. Macquart[8] and Vauquelin,[9] in the gastric juice of the ruminant animal, found albumen and free phosphoric acid.[10] All these analyses were made on the mixed fluid, to which the term *gastric juice* has been applied. That such a mixed fluid does exist in the stomach at the time of chymification, and is largely concerned in the process, is proved by the facts already mentioned, as well as by the following. M. Magendie[11] asserts, that one of his pupils—M. Pinel—could procure, in a short time after swallowing a little water or solid food, as much as half a pint. M. Pinel "pos-

[1] Op. citat., p. 139. [2] Expériences sur la Digestion, § 81, Genèv., 1783.
[3] Principes de Physiologie, Paris, 1806.
[4] Tractatus Novus de Primâ Coctione, &c., Genev., 1691.
[5] Observations on Certain Parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 134, Philad., 1840. [6] In Spallanzani, § 244.
[7] Ricerche sulla Natura, &c., del Succo Gastrico, Milano, 1785; or Journal Phys., t. xxiv.
[8] Mém. de la Société de Méd., Paris, 1786. [9] Fourcroy, Élém. de Chim., tom. iv.
[10] See Burdach, Die Physiologie als Erfahrungswissenschaft, v. 240 und 431, Leipzig, 1835. [11] Précis, &c., ii. 11.

sessed the faculty of vomiting at pleasure." In this way, he obtained from his stomach, in the morning, about three ounces of fluid, which was analyzed by M. Thénard, who found it composed of a considerable quantity of water, a little mucus, and salts with a base of soda and lime; but it was not sensibly acid, either to the tongue or to reagents. On another occasion, M. Pinel obtained two ounces of fluid in the same manner. This was analyzed by M. Chevreul, and found to contain much water, a considerable quantity of mucus, lactic acid—united to an animal matter, soluble in water, and insoluble in alcohol,—a little muriate of ammonia, chloride of potassium, and some chloride of sodium.

Messrs. Tiedemann and Gmelin[1] procured the gastric fluid by making animals, that had fasted, swallow indigestible substances, as flints. It always appeared to them to be produced in greater quantity, and to have a more acid character, in proportion as the alimentary matter was less digestible and less soluble; and they assign it, as constituents,—chlorohydric acid; acetic acid; mucus; no, or very little, albumen; salivary matter; osmazome; chloride of sodium, and sulphate of soda. In the ashes, remaining after incineration, were, carbonate, phosphate, and sulphate of lime, and chloride of calcium. MM. Leuret and Lassaigne[2] assign its composition, in one hundred parts, to be,—water, ninety-eight; lactic acid; muriate of ammonia; chloride of sodium; animal matter soluble in water; mucus; and phosphate of lime, two parts. M. Braconnot[3] examined the gastric juice of a dog, and found it to contain—free chlorohydric acid in great abundance; muriate of ammonia; chloride of sodium in very great quantity; chloride of calcium; a trace of chloride of potassium; chloride of iron; chloride of magnesium; colourless oil of an acid taste; animal matter soluble in water and alcohol, in very considerable quantity; animal matter soluble in weak acids; animal matter soluble in water, and insoluble in alcohol (*salivary matter* of Gmelin); mucus; and phosphate of lime. In the winter of 1832–3, the author was favoured by Dr. Beaumont,[4] with a quantity of the gastric secretion obtained from the individual with the fistulous opening into the stomach, which was examined by himself, and his friend, the late Professor Emmet, of the University of Virginia, and found to contain free chlorohydric and acetic acids, phosphates, and chlorides, with bases of potassa, soda, magnesia, and lime, and an animal matter—probably *pepsin*—soluble in cold water, but insoluble in hot. The quantity of free chlorohydric acid was surprising: on distilling the fluid, the acids passed over, the salts and animal matter remaining in the retort: the amount of chloride of silver thrown down on the addition of the nitrate of silver to the distilled fluid, was astonishing. The author had many opportunities for examining the gastric secretion obtained from the case in question. At all times, when pure or unmixed except with a portion of the mucus of the lining membrane of the digestive tube, it was a transparent fluid, having a marked smell of chlorohydric acid; and of a slightly

[1] Op. cit. [2] Recherches, &c., Paris, 1825.

[3] Journal de Chimie Médicale, tom. ii., ser. 2, 1836, and Records of General Science, Jan., 1836.

[4] See a letter from the author to Dr. Beaumont, in Beaumont's Experiments, &c., on the Gastric Juice, p. 77; and the author's Elements of Hygiene, p. 216, Philad., 1835.

salt, and very perceptibly acid, taste. It matters not, therefore, that M. Blondlot,[1] in his experiments on the gastric secretions of dogs and other animals, obtained by artificial fistulous openings made into the stomach, did not find, when distilled, that they exhibited any acid reaction, whilst the residue in the retort was always strongly acid. The results referred to by the author as regards the gastric juice of man were positive and uniform; and established, that it always contains a large quantity of chlorohydric acid.

Moreover, free chlorohydric acid was found in the gastric juice of animals by Enderlin,[2] Hübbenet,[3] and Bidder and Schmidt.[4] Funke[5] is of opinion that their researches leave no doubt on the subject of its presence; and Dr. Brinton,[6] after an inquiry into the whole matter, thinks "there seems little doubt that we ought to regard the balance of evidence as inclining decisively towards a single gastric acid," and that acid the chlorohydric. Schmidt is of opinion, that the essential gastric acid is the chlorohydric, and believes it to be a conjugated acid in union with pepsin—chloro-pepso-hydric acid—*chlorpepsinwasserstoffsäure;*—the existence of which is hypothetical.[7] More recently, Grünewaldt[8] has had an opportunity of instituting a variety of experiments in a case of fistulous opening into the stomach of a woman. Three analyses of the fluid obtained were made by Schmidt, who found the mean to be as follows:—

Water	99.44
Solid residue	0.56
Ferment, &c.	0.32
Inorganic constituents	0.24
Chlorohydric acid	0.02
Chloride of potassium	0.06
" of sodium	0.15
" of calcium	0.006
Phosphate of lime, magnesia, and iron	0.013

From this analysis it is manifest, that the proportion of water is very great. It would seem, indeed, that an enormous amount of fluid is secreted from the stomach in the twenty-four hours. It has been attempted to estimate the amount by that of the albuminous matter known to be dissolved by it; but all calculations thus made must be vague and uncertain. Certain aliments are known to occasion a more copious secretion of the gastric solvent than others; and those nitrogenized substances which remain longest in the stomach will require

[1] Traité Analytique de la Digestion, Paris, 1844. An abstract of his views is given by Mr. Paget, Brit. and For. Med. Rev., Jan., 1845, p. 270; see, also, Gazette Médicale de Paris, 1851, No. 33, p. 526.

[2] Canstatt, Jahresbericht, 1843, i. 149.

[3] Disquisitiones de Succo Gastrico, Dorp. Liv. 1850: and Canstatt, op. cit., 1851, s. 97, and 1852, s. 109.

[4] Die Verdauungsäfte und der Stoffwechsel, s. 46, Mitau und Leipzig, 1852.

[5] Rudolph Wagner's Lehrbuch der Speciellen Physiologie, von D. Otto Funke, s. 163, Leipz., 1854.

[6] Art. Stomach and Intestines in Cyclop. of Anat. and Physiol., Pt. 46, p. 332, June, 1855.

[7] Moleschott, Physiologie des Stoffwechsels, u. s. w., s. 428, Erlangen, 1851; and Lehmann, Lehrbuch der Physiologisch. Chemie, iii. 330, Leipz., 1852.

[8] Succi Gastrici Humani Indoles, &c., Dorpat, 1853; Vierordt's Archiv. für Physiol. Heilkund. xiii. 459; and Canstatt, 1854, i. 145, Würzburg, 1855. Grünewaldt found free chlorohydric acid in smaller proportion in man than in animals.

a greater amount of fluid. Lehmann[1] estimates the daily quantity in man to be about four pounds; whilst Bidder and Schmidt,[2] founding their deductions on experiments on dogs with gastric fistulæ, infer that in that animal as much as one-tenth of its weight is daily secreted; and Grünewaldt,[3] from his experiments on the woman with the gastric fistula, was led to infer that the secretion amounts to the enormous quantity of from one-fifth to one-quarter of the weight of the body daily! Of course, a large amount of this fluid passes again into the circulation along with the products of digestion that are dissolved in it.[4] Still, the amount is so vast, it is difficult to imagine that there is not some error in the observation, or fallacy in the deductions.

After this it seems unnecessary to examine into the statement of M. Blondlot, that the true and almost only source of the acidity of healthy gastric fluid is the presence of acid phosphate salts. If, at least, we admit this to be the case in animals, it is assuredly not so in man. The remark applies equally to the experiments of Dr. R. D. Thompson on the gastric secretions of the sheep and pig.[5] By these observers, the results obtained from the examination of the gastric secretions in man, seem to have been passed over, and they have deduced their inferences from those of animals, which may, in part—but in part only—account for the great discrepancy in their statements.[6]

The source of the chlorine or chlorohydric acid in the gastric juice, as Dr. Prout[7] suggests, must be the common salt existing in the blood, which, he conceives, is decomposed by galvanic action: the soda, set free, remaining in the blood, a portion being "requisite to preserve the weak alkaline condition essential to the fluidity of the blood;" but the larger part being directed to the liver to unite with the bile. This is plausible; but, it need scarcely be added, not the less hypothetical. Drs. Purkinje and Pappenheim[8] are of a similar opinion in regard to the source of the chlorohydric acid. From their galvanic experiments they think it follows, that the juices mixed with the food in the natural way, saliva, mucus, the portions of chloride of sodium present therein, and still more the gastric mucous membrane itself, develope as much as is required: and that if the nervous action in the stomach be either identical with, or analogous to, galvanism, it would be sufficient to account for the secretion of the quantity of chlorohydric acid requisite for digestion, without the assumption of a special organ of secretion.[9]

M. Blondlot[10] denies—and Liebig[11] formerly did likewise—that in

[1] Lehrbuch der Physiologischen Chemie, ii. 49, and iii. 330, 342, Leipz., 1852, or Translation by Dr. Day, Amer. edit. by Dr. R. E. Rogers, i. 448 and ii. 520, Philad., 1855.

[2] Op. cit., s. 36.

[3] Op. cit.

[4] See on the Gastric Juice and its office in Digestion, Dalton, Amer. Journ. of the Med. Sciences, Oct., 1854, p. 317.

[5] Ranking's Abstract, vol. i., Pt. 2, Amer. edit., p. 271, New York, 1846.

[6] Carpenter, Principles of Physiology, 4th Amer. edit., p. 494. Philad., 1850; and Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 170, Philadelphia, 1853.

[7] Bridgewater Treatise, Amer. edit., p. 268, Philad., 1834.

[8] Müller's Archiv. für Anatomie, u. s. w. Heft 1, 1838, noticed in Brit. and For. Med. Rev., Oct., 1838, p. 529.

[9] See also Dr. Brinton, loc. cit.

[10] Op. cit.

[11] Animal Chemistry, Gregory's and Webster's edit., p. 107, Cambridge, 1842.

health lactic acid exists in the stomach. In certain diseases, according to the latter, both it and mucilage are formed from the starch, and sugar of the food; and he affirms, that the property possessed by these substances of passing, by contact with animal substances, in a state of decomposition, into lactic acid, has induced physiologists without farther inquiry, to assume that lactic acid is produced during digestion. He now, however, admits its existence in health,[1] and with Dr. R. D. Thompson, MM. Bernard and Barreswil, Frerichs,[2] J. Béclard,[3] and others, consider it to be an important agent in the digestive process. With some other chemists, he denies the existence of free chlorohydric acid in the stomach, and believes, that when it is obtained by the simple distillation of the gastric juice it is formed by the reaction of the lactic and phosphoric acids, which are present in the fluid, on the chlorides; and Lehmann[4] found, when he experimented on the stomachs of dogs placed in vacuo in such a manner as to cause the vapours from the gastric juice to pass through a tube containing a solution of nitrate of silver, that there was no indication of free chlorohydric acid until the fluid had become so concentrated as to permit the action of the lactic acid on the earthy chlorides. His results would tend to confirm the later conclusions of Liebig, as well as those of MM. Bernard and Barreswil, and others, as to the nature of the acid of the gastric juice of certain animals at least.[5] It is proper to remark, however, that neither Prout nor Braconnot could detect lactic acid in the gastric juice; and, moreover, it does not appear to be formed in artificial digestion.[6]

The diversity of results obtained by chemical analysis; the difficulty of comprehending how the same fluid can digest substances of such opposite character; and the uncertainty we are in, regarding the organs concerned in its production, had led some physiologists to doubt the existence of any such *gastric juice* or solvent as that described by Spallanzani. M. Montègre,[7] for example, in the year 1812, presented to the French Institute a series of experiments, from which he concluded, that the gastric juice of Spallanzani is nothing more than saliva, either in a pure state, or changed by the chymifying action of the stomach and become acid. As M. Montègre was able to vomit at pleasure, he obtained the gastric juice, as it had been done by previous experimenters, in this manner, whilst fasting. He found it frothy, slightly viscid, and turbid; depositing, when at rest, some mucous flakes; and commonly acid; so much so, indeed, as to irritate the throat, and render the teeth rough. He was desirous of proving, whether this fluid was in any manner inservient to chymification. For this purpose, he began

[1] Chemistry of Food, London, 1847.
[2] Canstatt, Jahresbericht, 1850, Bd. i. s. 134.
[3] Traité Élémentaire de Physiologie, p. 86, Paris, 1855.
[4] Lehrbuch der Physiologischen Chemie, ii. 42, Leipz., 1852, or Amer. edit. of Dr. Day's translation by Dr. Robt. E. Rogers, i. 441, Philad. 1855.
[5] Archiv. der Pharmacie, cited in the British and Foreign Medico-Chirurgical Review, p. 261, Jan., 1849.
[6] A full account of the various views in regard to the gastric acid is given by Frerichs, Art. Verdauung, Wagner's Handwörterbuch der Physiologie, 21ste Lieferung, s. 780, Braunschweig, 1849; and Bérard, Cours de Physiologie, 11e Livraison, p. 97, Paris, 1849.
[7] Expér. sur la Digestion, p. 20, Paris, 1824.

by ejecting as much as possible by vomiting; and, afterwards, swallowed magnesia to neutralize what remained. On eating afterwards, the food did not appear less chymified, nor was it less acid; whence he concluded, that, instead of the fluid being the agent of chymification, it was nothing more than saliva and the mucous secretions of the stomach, changed by the chymifying action of that viscus. To confirm himself in this view, he repeated with it, Spallanzani's experiments on artificial digestion; making, at the same time, similar experiments with saliva: the results were the same in both cases. When gastric juice, not acid, was put into a tube, and placed in the axilla,—as in Spallanzani's experiments,—in twelve hours it was in a complete state of putrefaction. The same occurred to saliva placed in the axilla. Gastric juice, in an acid state, placed there, did not become putrid, but this seemed to be owing to its acidity; for the same thing happened to saliva, when rendered acid by the addition of a little vinegar; and even to the gastric juice,—used in the experiment just referred to,—when mixed with a little vinegar. Again:—he attempted artificial digestion with the gastric juice, acid and not acid; fresh and old; but they were unsuccessful. The food always became putrid; but sooner when the juice employed was not acid; and, if it sometimes liquefied before becoming putrid, this was attributed to the acidity of the juice, as the same effect took place, when saliva, mixed with a little vinegar, was employed. M. Montègre, moreover, observed, that the food rejected from the stomach was longer in becoming putrid, in proportion to the time it had been subjected to the chymifying action of the stomach; and he concluded, that the fluid, which is sometimes contained in the empty stomach, instead of being a menstruum kept in reserve for chymification, is nothing more than the saliva continually sent down into that viscus, and that its purity or acidity depends upon the chymifying action of the stomach.[1]

As regards the fluid met with in the stomach of fasting animals, M. Montègre's remarks may be true in the main; but we have too many evidences in favour of the chemical action of some secretion from the stomach during digestion to permit us to doubt the fact for a moment. Besides, some of M. Montègre's experiments have been repeated with opposite results. MM. Leuret and Lassaigne,[2] and Dr. Beaumont[3] performed those relating to digestion after the manner of Spallanzani, and succeeded perfectly; whilst they failed altogether in producing chymification with saliva, either in its pure state, or when acidulated with vinegar.

By steeping the mucous membrane of an animal's stomach in an acid liquor, a solution is obtained, to which Eberle[4] gave the name *pepsin*. This solution has the property of dissolving organic matter in a much higher degree than diluted acids. It dissolves coagulated albumen, muscular fibre, and animal matters in general. In an experiment, one grain of the digestive matter dissolved one hundred grains of coagulated white of egg. Eberle thought that all mucus has the

[1] Chaussier and Adelon, in Dict. des Sci. Médicales, xx. 422.

[2] Recherches sur la Digestion, Paris, 1825. [3] Op. citat., p. 139.

[4] Physiologie der Verdauung nach Versuchen, u. s. w., Würzburg, 1834; Müller, Archiv., Heft 1, 1836, or London Lancet, p. 19, March 31, 1838.

property, when acidulated, of inducing decomposition and subsequent solution of the food; but it would appear, that no other mucus than that of the gastric mucous membrane, when acidulated, possesses it,[1] and, consequently, that there must be a peculiar substance, *pepsin* or *gastric ferment*, which may be regarded as a true digestive principle.[2] This principle was not obtained by Schwann in a pure state; but M. Wasmann[3] would appear to have succeeded better. A solution, containing only $\frac{1}{5000}$ part of pepsin and slightly acidulated, is said to dissolve the white of an egg in six or eight hours.[4] It is not generally considered, however, to be a distinct substance—an immediate principle; but rather to be the product of an alteration of the nitrogenized matters of the parietes of the stomach.[5]

An artificial digestive fluid is sometimes made which resembles that of the human stomach, by macerating in water portions of fresh or dried mucous membrane of the stomach of a pig or other omnivorous animal, or of the fourth stomach of the calf, and adding to the infusion a few drops of chlorohydric acid, about 3.3 grains to half an ounce of the mixture according to Schwann. Portions of food placed in this fluid, and the mixture kept at a temperature of about 100°, are softened and changed, much in the same manner as they would be in the stomach.[6]

Even were the evidence adduced less positive in favour of the existence of some gastric secretion concerned in the digestive changes in that organ, the following phenomena would be overwhelming. Besides the fact of the most various and firm substances being reduced to chyme in the stomach, we find the secretions from its lining membrane possessing the power of coagulating albuminous fluids. It is upon the coagulating property of these secretions, that the method of making cheese is dependent. Rennet, employed for this purpose, is an infusion of the digestive stomach of the calf, which, on being added to milk, converts the albuminous portion into curd; and it is surprising how small a quantity is necessary to produce this effect. Messrs. Fordyce[7] and Young,[8] of Edinburgh, found that six or seven grains of the inner coat of a calf's stomach, infused in water, afforded a liquid, which coagulated more than one hundred ounces of milk,—that is, more than six thousand eight hundred and fifty-seven times its own weight; and yet its weight was probably but little diminished. The substance that possesses this property does not appear to be very soluble in water; for the inside of a calf's stomach, after having been steeped in water for six hours, and well washed, still furnishes a liquor or infusion, which coagulates milk. Liebig[9] has denied, that the fresh

[1] Müller, Elements of Physiology, by Baly, pp. 518 and 542, London, 1838.

[2] Müller and Schwann, in Müller's Archiv., Heft 1, 1836; and Müller, op. citat.

[3] Journ. de Pharmacie; and American Journal of Pharmacy, for Oct., 1840, p. 192.

[4] Graham's Elements of Chemistry, Amer. edit., p. 695, Philad., 1843, and Thomson's Animal Chemistry, p. 229, Edinb., 1843.

[5] Robin and Verdeil, Traité de Chimie Anatomique, &c., iii. 555, Paris, 1853; and Becquerel and Rodier, Traité de Chimie Pathologique, p. 470, Paris, 1853.

[6] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 173, Philad., 1853.

[7] A Treatise on the Digestion of Food, p. 57, 2d edit., Lond., 1791.

[8] Thomson's System of Chemistry, 6th edit., iv. 596.

[9] Animal Chemistry, Webster's Amer. edit., Cambridge, 1842.

lining membrane of the stomach of the calf, digested in weak chlorohydric acid, gives to that fluid the power of dissolving boiled flesh or coagulated white of egg; but Dr. Pereira[1] affirms, that he has found, by experiment, that a digestive liquor can be prepared from the fresh undried stomach of a calf. This had, indeed, been shown on the best authority long ago. Mr. Hunter, for example, made numerous experiments upon the coagulating power of the secretions of the stomach, which show, that it is found in the stomachs of animals of very different classes. The lining of the fourth stomach of the calf is in common use, in a dried state, for the purpose mentioned above; and it has been proved, that every part of the membrane possesses the same property. Mr. Hunter found, by experiment, that the mucus of the fourth cavity of a slink calf, made into a solution with a small quantity of water, had the power of coagulating milk; but that found in the three first cavities possessed no such power. The former, even after it had been kept several days, and was beginning to be putrid, retained the property. The duodenum and jejunum, with their contents, likewise coagulated milk; but the process was so slow as to give rise to the suggestion, that it might have occurred independently of the intestines employed for the purpose. He found, that the inner membrane of the fourth cavity in the calf, when old enough to be killed for veal, had the same property. Portions of the cuticular, of the massy glandular part, and of the portion near the pylorus of the boar's stomach, being prepared as rennet, it was found, that no part had the effect of producing coagulation but that near the pylorus, where the gastric glands of the animal are especially conspicuous. The crop and gizzard of a cock were salted, dried, and afterwards steeped in water. The solution, thus obtained, was added to milk: the portion of the crop coagulated it in two hours; that of the gizzard in half an hour. The contents of a shark's stomach and duodenum coagulated it instantaneously. Pieces of the stomach were washed clean, and steeped in water for sixteen hours. The solution coagulated milk immediately. Pieces of the duodenum produced the same effect. When the milk was heated to 96°, the coagulation took place in half an hour; when cold, in an hour and a quarter. The stomachs of the salmon and thornback, made into rennet, coagulated milk in four or five hours.

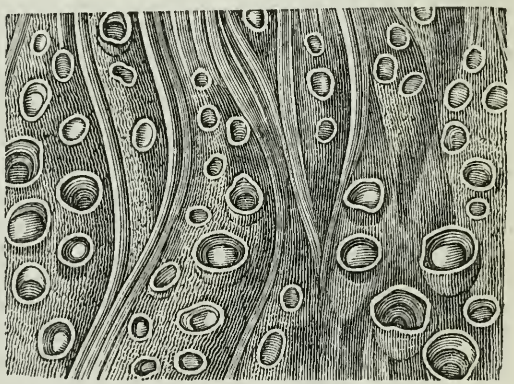
But those experiments of Mr. Hunter do not inform us of the particular secretions that are productive of the effect. They would, indeed, rather seem to show, that it is a general property of the whole internal membrane. To discover the exact seat of the secretion, and especially whether it be not in the gastric glands, Sir Everard Home[2] selected those of the turkey; which, from their size, are better adapted for such an experiment than those of any other bird, except the ostrich. A young turkey was kept a day without food, and then killed. The gastric glands were carefully dissected separately from the lining of the cardiac cavity; cutting off the duct of each before it pierced the membrane, so that no part but the glands themselves were removed.

[1] Treatise on Food and Diet, Amer. edit., p. 36, New York, 1843.
[2] Lectures on Comparative Anatomy, i. 299, Lond., 1814, and iii. 134, Lond., 1823.

Forty grains, by weight, of these glands were added to two ounces of new milk; and similar experiments were made with rennet; with the lining of the cardiac cavity of the turkey; and with the inner membrane of the fourth cavity of the calf's stomach. Coagulation and separation into curds and whey were first effected by the rennet. Next to this, and simultaneously, came the gastric glands, and the fresh stomach of the calf; and lastly, the cardiac membrane of the turkey. From these experiments, Sir Everard concluded, that the power of coagulation is in the secretion of the gastric glands; and that the power is communicated to other parts, by their becoming more or less impregnated with it.

The marginal figure, copied from an engraving of the microscopic observations of Mr. Bauer, exhibits the gastric glands—as he regarded them—of the human œsophagus magnified fifteen times. These glands are in the lining of the lower part of the œsophagus; and have the appearance of infundibular cells, whose depth does not exceed the thickness of the membrane. This structure, although different from that of the gastric glands of birds, is a nearer approach to it than is to be met with in any part of the inner surface of the stomach or duodenum. It also resembles them, in the secretion which it produces coagulating milk, whilst none of the inspissated juices, met with in these cavities, according to Sir Everard, affect milk in the same way. From these facts, he thinks, there can be no longer any doubt entertained, that the gastric glands have the same situation respecting the cavity of the stomach as in birds. No histologist, however, agrees with him in this location of the gastric glands.

Fig. 53.



Gastric Glands of the Œsophagus magnified fifteen times.

In some experiments, undertaken by M. J. F. Simon[1] with a view to determine, whether the stomach of the child possesses the same properties of coagulating milk as that of the calf, he found that cow's milk was not coagulated by it, but that, when a quantity of the colostrum of the mother of a child, which died when five days old, was obtained, and a piece of calf's stomach was introduced into it, the milk coagulated.

Another property, manifestly possessed by the secretion in question, is that of preventing putrefaction, or of obviating it in substances exposed to its action. Montègre and Thackrah[2] deny it this property, but there can be no doubt of its existence. Spallanzani, Fordyce, and

[1] Müller's Archiv., Heft 1, 1839, cited in Brit. and For. Med. Rev., Oct., 1839, p. 549.
[2] Lectures on Digestion and Diet, p. 14, Lond., 1824.

others, have ascertained, that in those animals which frequently take their food in a half putrid state, the first operation of the stomach is to disinfect, or remove the fœtor from the aliment received into it. We have already alluded to many facts elucidative of this power. Helm of Vienna,[1] in the case of a female who had a fistulous opening in her stomach, observed, that substances which were swallowed in a state of acidity or putridity, soon lost those qualities in the stomach; and the same power of resisting and obviating putrefaction has been exhibited in experiments made out of the body. Nothing could be more unequivocal, as regards the possession of this property by the gastric fluid, than the experiments of Dr. Beaumont and the author,[2] with the secretion obtained from the subject of his varied investigations. In the presence of the author's friend, N. P. Trist, Esq.—then consul of the United States at Havana,—the odour of putrid food was as speedily removed by it as by chlorinated soda employed at the same time on other portions. The explanation of this property, as well as that of coagulation, has been a stumbling-block to the chemical physiologist. "We can only say concerning it," says Dr. Bostock,[3] "that it is a chemical operation, the nature of which, and the successive steps by which it is produced, we find it difficult to explain; at the same time, that we have very little, in the way of analogy, which can assist us in referring it to any more general principle, or to any of the established laws of chemical affinity."

The cases of what are termed *digestion of the stomach after death* afford us, likewise, remarkable examples of the presence of some powerful agent in the stomach; as well as of the resistance to chemical action, offered by living organs. Powerful as the action of the gastric juice may be, in dissolving alimentary substances, it does not exert it upon the coats of the stomach during life. Being endowed with vitality, they effectually resist it. But when that viscus has lost its vitality, its parietes yield to the chemical power of the contained juices, and become softened, and, in part, destroyed. Mr. Hunter[4] found the lining membrane of the stomach destroyed, in several parts, in the body of a criminal, who, for some time before his execution, had been prevailed upon, in consideration of a sum of money, to abstain from food. Since Hunter's time, numerous examples have occurred, and been recorded by Messrs. Baillie, Allan Burns, Haviland, Grimaud, Pascalis, Cheeseman, J. B. Beck, Chaussier, Yelloly, Gardner, Treviranus, Gödecke, Jäger, Carswell, and others.[5] The fact is of importance in medical jurisprudence; and, until a better acquaintance with the subject, would, doubtless, have been set down as strong corroborative evidence in cases

[1] Rudolphi, Grundriss der Physiologie, 2er Band, 2te Abtheil., s. 114, Berlin, 1828.

[2] See the author's Elements of Hygiene, p. 216, Philad., 1835.

[3] Edit. citat., p. 571.

[4] Phil. Transact., lxii.; and Observations on certain parts of the Animal Economy, with notes by Prof. Owen, Amer. edit., p. 144, Philad., 1840.

[5] Beck's Medical Jurisprudence, 6th edit., ii. 311, Albany, 1838; Carswell's Path. Anat., No. 5, Lond., 1833; and T. Wilkinson King, Guy's Hospital Reports, vii. 139, Lond., 1842; and a case communicated to the author by Dr. Thomas M. Flint, in which the stomach had separated from the œsophagus, recorded in Med. Examiner, p. 715, for December, 1848; also, Dr. George Budd, on the Organic Diseases and Functional Disorders of the Stomach, Amer. edit., p. 19, Philad., 1856.

of suspected poisoning. It is now established that solution of the stomach may take place after death, without there being reason for supposing that any thing noxious had been swallowed.

The experiments of Dr. Wilson Philip[1] and Sir Robert Carswell[2] are corroborative of this physiological action of the gastric juice. On opening the abdomen of rabbits, that had been killed immediately after having eaten, and allowed to lie undisturbed for some time before examination, the former found the great end of the stomach soft, eaten through, and sometimes altogether consumed; the chyme being covered only by the peritoneal coat, or lying quite bare for the space of an inch and a half in diameter: and, in this last case, a part of the contiguous intestines was also destroyed; whilst the cabbage, which the animal had just taken, lay in the centre of the stomach unchanged, if we except the alteration that had taken place, in the external parts of the mass it had formed, in consequence of imbibing gastric fluid from the half-digested food in contact with it. Why the perforation takes place, without the food being digested, is thus explained by Dr. Philip. Soon after death, the motions of the stomach, which are constantly carrying on the most digested food towards the pylorus, cease. The food, that lies next to the surface of the stomach, thus becomes fully saturated with gastric fluid; neutralizes no more; and no new food being presented to the fluid it acts on the stomach itself, now deprived of life, and equally subjected to its action with other dead animal matter. It is extremely remarkable, however, that the gastric fluid of the rabbit, which, in its natural state, refuses animal food, should so completely digest the stomach, as not to leave a trace of the parts acted upon. Dr. Philip remarks, that he has never seen the stomach eaten through except at the larger end; but, in other parts, the external membrane has been injured. Mr. A. Burns,[3] however, affirms, that in several instances he found the forepart of the stomach perforated about an inch from the pylorus, and midway between the smaller and larger curvatures.

From all these facts, then, we are justified in concluding, that the food in the stomach is subjected to the action of secretions, which alter its properties, and are the principal agents in converting it into chyme.

But many physiologists, whilst they admit, that the change effected in the stomach is of a chemical character, contend, that the nature of the action is unlike what takes place in any other chemical process, and is, therefore, necessarily *organic* and *vital*, and appertaining to *vital chemistry*. Such are the sentiments of Messrs. Fordyce,[4] Broussais,[5] Chaussier, and Adelon,[6] and others. Dr. Prout suggests, that the stomach must have, within certain limits, the power of *organizing* and *vitalizing* the different alimentary substances; so as to render them fit for being brought into more intimate union with a living body, than

[1] Treatise on Indigestion, Lond., 1821.

[2] Ibid. and Edinb. Med. and Surg. Journal, Oct.. 1830; and art. Perforation of the Hollow Viscera, in Cyclopædia of Practical Medicine, P. xvi. p. 272, Lond., 1833.

[3] Edinb. Med. and Surg. Journal, vi. 132.

[4] On the Digestion of Food, 2d edit., Lond., 1791.

[5] Traité de Physiologie, &c., translated by Drs. Bell and La Roche, p. 323.

[6] Dict. des Sciences Médicales, ix.

the crude aliments can be supposed to be. It is impossible, he conceives, to imagine, that this organizing agency of the stomach can be chemical. It is vital, and its nature completely unknown. The physiologist should not, however, have recourse to this explanation, until every other has failed him. It is, in truth, another method of expressing his ignorance, when he affirms, that any function is executed in an *organic* or *vital* manner; nor is this mode of explaining the conversion of the aliment into chyme necessary; the secretion of the matters that are the great agents of chymification is doubtless vital; but when once secreted, the changes, effected upon the food, are probably unmodified by any vital interference, except what occurs from temperature, agitation, &c., which can only be regarded as auxiliaries in the function. It is in this way, that digestion is influenced by the nervous system.

The effect of the different emotions on the digestive function is often evinced, and has already been alluded to; but the importance of the nervous influence to it has been elucidated, in an interesting manner to the physiologist, of late years chiefly. Baglivi,[1] having tied the nerves of the eighth pair on dogs, found that they were affected with nausea and vomiting, and obstinately refused food. Since Baglivi's time, the same results have been obtained by many physiologists. M. De Blainville, having repeated the operation on pigeons, found the vetch in their crops entirely unchanged, and chymification totally prevented. Legallois,[2] Sir Benjamin Brodie,[3] Messrs. Philip,[4] Dupuy, Clarke Abel, Hastings,[5] and others—on carefully repeating the experiments—announced, that, after this operation, the digestive process was entirely suspended.[6] The result of these experiments was, however, contested by several physiologists of eminence, who affirmed, that, after the division of the eighth pair, digestion continued nearly in the natural state, or, at most, was only slightly impeded. Mr. Broughton[7] asserted, that he had made the section on eleven rabbits, one dog, and two horses; and that digestion was not destroyed. M. Magendie[8] expresses his belief, that the arrest of chymification, where it was observed, was owing to the disturbance of respiration caused by the division of the nerves; and he states that digestion continued when care was taken to cut the nerve within the thorax, lower down than the part which furnishes the pulmonary branch. MM. Leuret and Lassaigue assert,[9] that they found chymification continue, notwithstanding the division of these nerves; and Dr. G. C. Holland[10] thinks he has proved, that the suspension of the digestive function is not produced by the influence of the nerves being withdrawn from the stomach, but by the disturbance of the circulatory system; for when the natural conditions of this system were maintained, after the division of the nerves, the function of digestion still continued to be properly performed; showing that the nervous connexion between

[1] Opera Omnia, Lugd. Bat., 1745.
[2] Sur le Principe de la Vie, p. 214, Paris, 1842.
[3] Phil. Trans. for 1814.
[4] Experimental Inquiry, &c., Lond., 1817.
[5] Journal of Science and Arts, vii. ix. x. xi. and xii.
[6] Ley, in App. to Laryngismus Stridulus, p. 447, Lond., 1836.
[7] Ibid., x. 292.
[8] Précis, &c., ii. 102.
[9] Edinburgh Med. and Surg. Journal, xciii. 365; and Recherches sur la Digestion, Paris, 1825.
[10] Inquiry into the Principles, &c., of Medicine, i. 444, Lond., 1834.

the brain and stomach is not essential to the process of digestion, the secretion of the gastric solvent, or the possession of contractility by the muscular fibres of the stomach.

In opposition to these experiments, those of M. Dupuytren may be adduced. He divided, separately, the portions of the eighth distributed to the pulmonary, circulatory, and digestive apparatuses, and always found, when the section was made below the pulmonary plexus, that chymification was suspended. But how are we to explain the discrepancy between these results, and those of Messrs. Broughton and Magendie? M. Adelon[1] has supposed, that as the eighth pair is not the only nerve distributed to the stomach,—the great sympathetic sending numerous filaments to it,—these filaments, in the experiments of Messrs. Broughton and Magendie, might have been sufficient to keep up for some time the chymifying action of the stomach; and, again, he suggests, whether the nervous influence may not have still persisted for a time after the section of the nerve, like other nervous influences, which, he conceives, continue for some time even after death; and, lastly, he thinks it probable, that, in the cases in which chymification continued, the experiment was badly performed. Most of these reasons, however, would apply with as much force to the experiments on the other side of the question. Why were not the agency of the great sympathetic, and the continuance of the nervous influence for some time after the section of the nerve, evidenced in the experiments of Dupuytren, Wilson Philip, Hastings, and others?

More recent experiments by Messrs. Wilson Philip,[2] Breschet, Milne Edwards, and Vavasseur,[3] have shown, that the mere division of the nerves, and even the retraction of the divided extremities for the space of one-fourth of an inch, does not prevent the influence from being transmitted along them to the stomach; but that if a portion of the nerve be actually removed, or the ends folded back, chymification is wholly or partly suspended.[4] Most of the experimenters agree with Sir Benjamin Brodie in the opinion, that chymification is suspended owing to the secretion of the gastric juice having been arrested by the division of the nerves under whose presidency it is accomplished. MM. Breschet and Milne Edwards, however, conceive, that the effect is owing to paralysis of the muscular fibres of the stomach produced by the section of the nerves; in consequence of which the different portions of the alimentary mass are not brought properly into contact with the coats of the stomach, so as to be exposed to the action of its secretions; and they affirm, that when the galvanic influence is made to pass along the part of the nerve attached to the stomach, its effect is to restore the due action of the fibres; and, that a mechanical irritant, applied to the lower end of the divided nerves, produces a similar kind of change on the food in the organ; from which they conclude, that the use of the par vagum, as connected with the functions of the stomach, is to bring the alimentary mass into necessary contact with the gastric secretions. These experiments were repeated in London by

[1] Physiologie de l'Homme, &c., 2de édit., vol. ii., Paris, 1829.
[2] Philos. Transact. for 1822. [3] Archives Générales de Méd., Août, 1823.
[4] Ware, North American Medical and Surgical Journal, Philad., 1828.

Mr. Cutler, under the inspection of Dr. Philip and Sir B. Brodie; but the effects of mechanical irritation of the lower part of the divided nerve did not correspond with those observed by MM. Breschet and Milne Edwards.[1]

The experiments of F. Arnold,[2] and of MM. Bouchardat and Sandras,[3] led them also to infer, that the nerves of the stomach appear to influence chymification in so far as the process depends upon the various motions of the organ.

M. Longet[4] has endeavoured to reconcile these discordant results. Having opened many dogs, he ascertained, that in the greater number, irritation of the pneumogastric nerves induced contraction of the stomach. Frequently, during his experiments, he saw the stomach assume the hour-glass form. In a few dogs, the movements of the stomach, on the irritation of the nerve, were scarcely perceptible. After repeating his experiments on forty dogs, he recognized that the difference in the results obtained depended on the condition of the stomach itself. Thus, if the animal was opened when it was full, irritation of the pneumogastric nerves caused manifest movement; but, when empty, scarcely any was excited: the movements, in fact, were feeble in proportion to the time that had elapsed from the period of chymification, or of filling the stomach. M. Longet thinks, that these facts account for the different results arrived at by experimentalists in regard to the influence of the pneumogastric nerves over the movements of the stomach; for, if the same experiments were made when the stomach was in different states, they might readily lead to opposite conclusions. He was never able to excite any movement of the coats of the stomach, by irritating or galvanizing the filaments of the great sympathetic or the semilunar ganglia.

On the whole, the proposition of Dr. Philip,—that if the eighth pair be divided in such a manner as to effectually intercept the passage of the nervous influence, digestion is suspended,—is generally considered to be established; although it must, we think, be admitted with Mr. Mayo,[5] that the rationale of the subject remains involved in great uncertainty. Like other secretions, that of the gastric juice, although capable of being modified by the nervous influence, cannot be regarded as immediately dependent upon it. The secretion, of the true acid character and solvent powers, is not always checked by the section of the nerves, and the experiments of Dr. John Reid[6] and others have sufficiently shown, that the integrity of those nerves is not a condition absolutely necessary for secretion in the stomach, whilst at the same time they prove, that the amount of secretions usually poured into the interior of that organ may be modified in an important manner by causes

[1] Bostock's Physiology, 3d edit., p. 523, London, 1836.

[2] Lehrbuch der Physiologie des Menschen, Zurich, 1836–7; noticed in British and Foreign Medical Review for Oct., 1839, p. 478.

[3] Annuaire de Thérapeutique, pour 1848, p. 283, Paris, 1848.

[4] Comptes Rendus, Févr., 1842. See, also, Bischoff, in Müller's Archiv., Berlin, 1843, and Prof. E. Weber, art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, s. 41, Braunschweig, 1846.

[5] Outlines of Human Physiology, 4th edit., p. 122, Lond., 1837.

[6] Edinb. Med. and Surg. Journal, April, 1839; and art. Par Vagum, in Cyclop. of Anat. and Physiol., pt. xxviii. p. 899, Lond., April, 1847.

acting through those nerves.[1] It is denied, however, by Professor J. Müller, that galvanism has any influence in re-establishing the gastric secretion, when it has been checked by their division.

Finally:—Dr. Philip found, that every diminution of the nervous influence,—the section of the medulla spinalis at the inferior part, for example,—deprives the stomach of its digestive faculty; and MM. Edwards and Vavasseur obtained the same result by the removal of a certain portion of the hemispheres of the brain, or by the injection of opium into the veins in sufficient quantity to throw the animal into deep coma. Much must, of course, be dependent on the deranging influence of the experiments. By means of the fistulous openings into the stomachs of dogs, first instituted by M. Blondlot, (see page 153,) M. Bernard[2] undertook fresh experiments on this unsettled topic. A dog's digestion was watched for eight days, and found to be well accomplished. On the ninth day, after twenty-four hours' fast, M. Bernard sponged out the stomach, which contracted on the contact of the sponge, and at once secreted a large quantity of gastric fluid. He then divided the pneumogastric nerves in the middle of the neck, and immediately the mucous membrane, which had been turgid, became pale, as if exanguious; the movements of the stomach ceased; the secretion of gastric fluid was instantaneously arrested, and a quantity of neutral ropy mucus was soon produced in its place. After this, digestion was not duly performed; milk was no longer coagulated; raw meat remained unchanged; and the food, consisting of meat, milk, bread, and sugar, which the dog had before thoroughly digested, remained for a long time neutral, and at length acquired acidity only from its transformation into lactic acid. In the stomachs of other dogs, after the division of the nerves, he traced the transformation of cane sugar into grape sugar in three or four hours; and in ten or twelve hours, the transformation into lactic acid was complete. In others, when the food was not capable of an acid transformation, it remained neutral to the last. In no case did any part of the food pass through the peculiar changes of chymification. More recently, MM. Bouchardat and Sandras,[3] from the results of a series of experiments instituted by them, believe they have established, that stomachal digestion and the movements of the organ are interrupted by the simultaneous section of both pneumogastrics on a level with the larynx; and farther, that intestinal digestion, and the production and absorption of a very laudable chyle persist notwithstanding such section; and M. Longet[4] concludes, that the section of the pneumogastrics seriously affects chymification, chiefly by paralysing the proper movements of the stomach, but partly by diminishing the secretion of the gastric solvent; and Professor Bérard,[5] after examining the different experiments and inferences of preceding inquirers, infers:—that "the mixed cords of the pneumogastrics and the branches furnished by the great sympathetic to the stomach beneath

[1] Longet, Traité de Physiologie, ii. 339, Paris, 1850.
[2] Gazette Médicale de Paris, 1 Juin, 1844.
[3] Bouchardat, Annuaire de Thérapeutique, de Matière Médicale, &c., pour 1848, p. 306, Paris, 1848.
[4] Traité de Physiologie, ii. 340, Paris, 1850.
[5] Cours de Physiologie, 12e livraison, p. 235, Paris, 1849.

the diaphragm, contribute to the maintenance of the contractility of the stomach and the secretion of the gastric juice. A greater share, however, ought to be assigned to the cords of the pneumogastric than to the sub-diaphragmatic branches of the great sympathetic. Moreover, the motor influence of the pneumogastric appears to predominate over the secretory; in other words, the resection of the nerve paralyses the movements more than it diminishes the secretion."

The experiments of Professor Bouley,[1] of Alfort, exhibit, that the results of dividing the pneumogastric nerves are very different in different animals. In the horse, for example, but little absorption is effected from the mucous membrane of the stomach, whilst in the dog the contrary is the case; hence, if the pneumogastric nerves be tied in the former animal, a solution of nux vomica is retained in the stomach unabsorbed; whilst if they were entire, it would be sent on rapidly into the small intestine, and be immediately absorbed. In the dog, the same toxical agent, on the other hand, rapidly destroys, whether the pneumogastric nerves be tied or not,—because the lining membrane of the stomach of the dog rapidly absorbs. The experiments of Prof. Bouley were repeated by Prof. Bérard, and with identical results. It is proper, also, to remark, that there are certain toxical agents, which are not absorbed by the mucous membrane of the stomach when the nerves are entire. This appears to be the case with the curare, which can be swallowed with impunity. It has been supposed, that this is owing to some change produced in it by the gastric secretions; but such would not seem to be the case, as the poison, if digested for 24 or 48 hours in gastric juice, is as virulent as ever; and such appears to be the fact when the various intestinal secretions are added to it. The experiments of MM. Bernard and Pelouze[2] exhibit, that the gastro-enteric mucous membrane refuses the passage of the curare under such circumstances, even when the experiment is made with a portion of the dead membrane adapted to an endosmometer. Such, too, appears to be the fact with other mucous membranes, except the pulmonary. If the poison be applied to it, absorption takes place in the same manner as when it is placed in the subcutaneous areolar tissue.

We can thus comprehend an experiment made by Professor Bernard, who gave to each of two dogs, on one of which he had divided the pneumogastric nerves, a dose of emulsin; and, half an hour afterwards, one of amygdalin; which are inert when taken alone, but, by mixture, produce hydrocyanic acid. The dog whose nerves were cut, died in a quarter of an hour; the emulsin having been detained in the stomach until the amygdalin reached it. In the other, the emulsin was removed by absorption, so that no hydrocyanic acid could be formed when the amygdalin was taken.[3] It is proper to remark, however, that the results of these distinguished observers do not exactly accord with those of Prof. Brainard, of Chicago, on curare furnished to him; and the active principle of which he believed to be the venom of serpents. Its effects

[1] Archives Générales de Médecine, Juillet, 1852, p. 357.
[2] L'Union Médicale, 1850, No. 125; and Brit. and For. Med.-Chir. Rev., April, 1851, p. 532.
[3] Frerichs, art. Verdauung, in Wagner's Handwörterbuch der Physiologie, S. 658, 3ter Band, 1ste Abth., Braunschweig, 1846.

on animals were strikingly like those caused by the venom of the rattlesnake, and in many cases no difference could be perceived between them. He found, too, that like the venom of serpents it was innocuous when taken into the stomach, "except, perhaps, when used in very large quantities, or in circumstances very peculiar. This is not the case with any known vegetable poison." Dr. Brainard adds, that "it is now well known, that the poison employed by the North American Indians for their arrows is that of the rattlesnake."[1] He affirms, moreover, that the curare or woorara poison may be taken into the stomach "and absorbed without any ill effects." If this be the case, some change must be produced in the venom before or during absorption. Dr. Brainard agrees, that the gastric juice has no power over it—"at least, that there is no evidence of its possessing such a power, and that all the facts that we are acquainted with go to disprove it." If absorbed, then, by what agency is it decomposed, for if injected into the bloodvessels it destroys rapidly?

Of all these theories of chymification, that of chemical action, aided by the collateral circumstances to be mentioned presently, can alone be embraced; yet, how difficult is it to comprehend, that any one secretion can act upon the immense variety of animal and vegetable substances employed as food! The discovery of the chlorohydric and acetic acids and of pepsin in the secretion, aids us in solving the mystery expressed by the well-known pithy and laconic observation of Dr. William Hunter in his lectures: "Some physiologists will have it, that the stomach is a mill; others, that it is a fermenting vat; others, again, that it is a stew-pan;—but, in my view of the matter, it is neither a mill, a fermenting vat, nor a stewpan;—but a stomach, gentlemen, a stomach."

Allusion has been already made to *pepsin*—an organic compound or "ferment" thrown off from the stomach—which is an active agent in digestion. It had been observed in the experiments of Eberle and Schwann, that although acids alone have little power in digesting food, they act energetically when combined with the mucus of the stomach. Eberle thought, that the acidulated mucus of any membrane would produce the effect, but J. Müller and Schwann found it to be restricted to that of the stomach. The agency of pepsin is regarded by Liebig[2] to be similar to that of *diastase* in the germination of seeds. Both are bodies in a state of transformation or decomposition; the latter effecting the solution of starch by its conversion into sugar; and the former the formation of alimentary matter into chyme. The present belief amongst physiologists and chemists—from all these experiments, as well as those of Wasmann and others—is, that pepsin, by inducing a new arrangement of the elementary particles or atoms of alimentary matter, disposes it to dissolve in the gastric acids. Chlorohydric acid, indeed, dissolves white of egg by ebullition, just as it does under the influence of pepsin; so that pepsin replaces the effect of a high temperature in the stomach.[3] Liebig, consequently, does not believe that the digestive

[1] Essay on a New Method of Treating Serpent Bite and other Poisoned Wounds, p. 8, Chicago, 1854.

[2] Animal Chemistry, Gregory and Webster's edit., p. 106, Cambridge, Mass., 1842.

[3] Graham's Elements of Chemistry, Amer. edit., by Dr. Bridges, p. 696, Philad., 1843.

process is a simple solution, but a species of fermentation, not identical, however, with any of the known processes of fermentation occurring in organic matters out of the body. It differs from ordinary fermentation in being unattended with the formation of carbonic acid; in not requiring the presence of oxygen, and in not being accompanied by the reproduction of the ferment.[1]

The deductions of MM. Bernard and Barreswil,[2] from numerous and varied experiments related to the *Académie Royale des Sciences*, of Paris, have been referred to already. From these, it would seem, that an organic compound of like nature exists in the saliva, gastric juice, and pancreatic fluid; and that its digestive powers vary according as it is associated with fluid having an acid or an alkaline reaction. Thus in the gastric juice, which is acid, it readily dissolves nitrogenized substances,—fibrin, gluten, albumen, &c., whilst it is altogether without action on starch. These gentlemen affirm, that if we destroy this acid reaction, and render the gastric juice alkaline by the addition of carbonate of soda, the active organic matter being in presence of an alkaline fluid changes its physiological action, and becomes able to modify starch rapidly, whilst it loses the power of digesting nitrogenized substances. As the saliva and pancreatic juice are alkaline, it was interesting to know whether a change in the chemical reaction of these fluids would produce in them the same change of properties as in the case of the gastric juice. Experiment proved such to be the fact. By rendering the pancreatic fluid or saliva acid, their ordinary action was inverted: they acquired the power of dissolving meat and other nitrogenized substances, whilst they lost their influence on starch.

Certain of the positions of these gentlemen received support from the investigations of M. Blondlot.[3] He is of opinion—and most of the physiologists of the present day accord with him—that of all the simple alimentary substances, those that are fluid at the ordinary temperature of the stomach, and those that are readily soluble in its secretions, as fluid albumen, sugar, gum, pectin, &c., are at once absorbed by the veins. It would seem, indeed, that in cases of scirrhus of the pylorus, and where a cancerous communication has existed between the stomach and colon,[4] nutritious matter must necessarily be absorbed from the stomach: except, however, in such cases, the view, that digestion can be accomplished by the gastric veins, independently of the action of any gastric secretions, can scarcely be maintained.[5] It would seem, moreover, that certain aliments, after having experienced the necessary stomachal and intestinal changes, are received by imbibition into the veins of the intestines. MM. Bouchardat and Sandras affirm, that after herbivorous animals have been fed on farinaceous substances, more dextrin, grape sugar and lactic acid are detected in the blood of the vena porta than in that of any other bloodvessel.[6] Trommer, also,

[1] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 173, Philad., 1853.

[2] Comptes Rendus, 9 Décemb., 1844, and 7 Juillet, 1845.

[3] Traité Analytique de la Digestion, Paris, 1844.

[4] Such a case is given by Dr. William Waters, in Philadelphia Med. Examiner, p. 201, April, 1845.

[5] A Physiological Essay on Digestion, by Nathan R. Smith, M. D., &c., New York, 1825.

[6] Gazette Médicale de Paris, Jan., 1845.

detected grape sugar in the blood of the portal vein, but not in that of the hepatic vein in animals to which that substance had been given with their food.[1] The bearing of such observations on the production of sugar by the liver will be shown hereafter.

In conclusion:—Let us inquire into the various agencies to which the food is exposed during the progress of chymification. *First.* It becomes mixed with the secretions, already existing in the stomach, as well as with those excited by its presence. *Secondly.* It is agitated by the peristaltic motion of the stomach itself, and the movement of the neighbouring organs. *Thirdly.* It is exposed to a temperature of at least 100° of Fahrenheit, which, during the ingestion of food, does not rise higher: exercise elevates, whilst sleep, or rest, or a recumbent posture, depresses it.[2] After food has been subjected to these influences, the conversion into chyme commences. This always takes place from the surface towards the centre: the nearer it lies to the surface of the stomach, the more it is acted on; and the part that is in contact with the lining membrane is more digested than any other;—appearing as if corroded by some chemical substance capable of dissolving it. Dr. Wilson Philip[3] asserts, that the new food is never mixed with the old; the former being always found in the centre, surrounded on all sides by the latter. If the old and new be of different kinds, the line of separation between them is so evident, that the former may be completely removed without disturbing the latter; and if they be of different colours, the line of demarcation can frequently be distinctly traced through the parietes of the stomach before they are laid open. Dr. Beaumont,[4] however, affirms, that this statement is not correct; that, in a very short time, the food, already in the stomach, and that subsequently eaten, become commingled. In the subject of his experiments, he invariably found that the old and new food, if in the same state of comminution, were readily and speedily combined.

The conversion of the food into chyme, it has been conceived, commences in the splenic portion, is continued in the body of the viscus, and completed in the pyloric portion. On this point, the observations of Dr. Philip differ somewhat from those of M. Magendie,[5] the former appearing to think, that chymification is chiefly accomplished in the splenic portion and middle of the stomach; whilst the latter affirms, that it is mainly in the pyloric portion that chyme is formed;—the alimentary mass appearing to pass into it by little and little, and during its stay there to undergo transformation. He further affirms, that he has frequently seen chymous matter at the surface of the alimentary mass filling the splenic half; but that it commonly preserves its properties in this part of the organ.

The precise steps of the change into chyme cannot be indicated. Some of the results, at different stages of the process, have been observed on animals; and pathological cases have occasionally occurred, which enabled the physiologist to witness what was going on in the interior of the stomach; but, with perhaps one exception, those oppor-

[1] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 194, Philad., 1853.
[2] Beaumont, On the Gastric Juice, p. 274.
[3] Exper. Inquiry, ch. vii. sect. 1; and Treatise on Indigestion, Lond., 1821.
[4] Op. citat., p. 89.
[5] Précis, &c., edit. cit., ii. 88.

tunities have not been much improved. Dr. Burrows[1] relates a case of fistulous opening into the organ. The subject of the case was not seen by him until twenty-seven years after the injury, at which time the man was, to all appearance, healthy; but he was drunken, and dissipated, and the following year died. A case is related by Shenck;[2] and Louis[3] refers to similar cases that occurred to Foubert and Covillard. Helm, of Vienna,[4] published a case, to which reference has already been made; and one of an interesting character occurred at the Hospital *La Charité* of Paris, which sheds some little light on the subject.[5] The aperture, which was more than an inch and a half long, and an inch broad, exposed the interior of the organ. At the admission of the female into the hospital, she ate three times as much as ordinary persons. Three or four hours after a meal, an irresistible feeling compelled her to remove the dressings from the fistulous opening, so as to allow the escape of food which the stomach could no longer contain,—when the contents came out quickly, accompanied by more or less air. They possessed a faint smell, but had neither acid nor alkaline properties; and the grayish paste, of which they consisted, when diluted with distilled water, did not affect vegetable blues. Digestion was far from complete; yet, frequently the odour of wine was destroyed; and bread was reduced to a soft, viscid, thick substance, resembling fibrin recently precipitated by acetous acid, and swimming in a stringy fluid of the colour of common soup. Experiments, made on this half-digested food, at the *École de Médecine*, showed that the changes, which it had undergone, were an increase of gelatin; the formation of a substance like fibrin; and a considerable portion of chloride of sodium, phosphate of soda and phosphate of lime. The patient could never sleep until she had emptied her stomach, and washed it out by drinking infusion of chamomile. In the morning, it contained a small quantity of thick, frothy liquid, analogous to saliva, which did not affect vegetable blues; with matters of greater consistence, and some opaque, albuminous flocculi mingled with the liquid portion. The results of chemical experiments on this liquid were similar to those obtained on the analysis of saliva.

But the most interesting case in its observed phenomena is one that occurred to Dr. Beaumont,[6] of the United States Army, now of Saint Louis, which the author had an opportunity of examining. To this case, reference has already been made repeatedly. A Canadian lad, Alexis San Martin, eighteen years of age, received a charge of buckshot in his left side, which carried away integuments and muscles of the size of the hand; fracturing, and removing the anterior half of the sixth rib; fracturing the fifth; lacerating the lower portion of the left lobe of the lung and the diaphragm, and perforating the stomach. When Dr. Beaumont saw the lad, twenty-five or thirty minutes after

[1] Transactions of the Royal Irish Academy, vol. iv.
[2] Observ. Medic. Rar., Nov., &c., lib. iii. Francof., 1609.
[3] Mémoir. de l'Académie Royale de Chirurgie, vol. iv. p. 213, Paris, 1819.
[4] Rudolphi, Grundriss der Physiologie, 2ter Band, 2te Abtheil, s. 114, Berlin, 1828.
[5] Richerand's Elémens de Physiologie, edit. cit., p. 72.
[6] Op. citat., Introduction, p. 10; and the Author's Elements of Hygiene, p. 216, Philad., 1835.

the accident, he found a portion of the lung, as large as a turkey's egg, protruding through the external wound, lacerated and burnt; and, immediately below this, another protrusion, which, on inspection, proved to be a portion of the stomach, lacerated through all its coats, and suffering the food he had taken at breakfast to escape through an aperture large enough to admit the forefinger. It need scarcely be said, that numerous untoward symptoms occurred in the cicatrization of so formidable a wound. Portions of the ribs exfoliated; abscesses formed to allow the exit of extraneous substances; and the patient was worn down by febrile irritation. Ultimately, however, the care and attention of Dr. Beaumont were crowned with success, and the instinctive actions of the system repaired the extensive injury. The wound was received in 1822, and on the 6th of June, 1823, one year from the date of the accident, the injured parts were sound, and firmly cicatrized, with the exception of the perforation leading into the stomach, which was about two inches and a half in circumference. Until the winter of 1823–4, compresses and bandages were needed to prevent the escape of the food. At this period, a small fold or doubling of the inner coat of the stomach appeared forming at the superior margin of the orifice, slightly protruding, and increasing in size until it filled the aperture. This valvular formation adapted itself to the opening into the organ, so as to completely prevent the escape of the contents, when the stomach was full; but it could be readily depressed by the finger. Since the spring of 1824, San Martin had enjoyed general good health; he was active, athletic, and vigorous; eating and drinking like a healthy individual. From the summer of 1825, Dr. Beaumont had been engaged in the prosecution of numerous experiments upon him; some of the results of which he has given to the world. In the winter of 1833, he was in Washington, when the author—at the time, Professor of Medicine in the University of Virginia—was politely invited to examine San Martin for physiological purposes. Many of the results of this examination are given by Dr. Beaumont, and have already been, or will be, referred to in the present work. Dr. Beaumont's researches into the comparative digestibility of different alimentary substances belong to another department of medical science, and have accordingly received attention from the author elsewhere.

What, then, it may be asked, are the changes wrought on the food in the stomach by the gastric secretions? Dr. Prout[1] classes them under three operations;—the *reducing*, *converting*, and *organizing* and *vitalizing*. The first of these is probably the main operation. In order to decide, whether the action of the stomach in digestion be a simple solution, or a total or partial conversion, certain compounds of organization, easy of detection—as *gelatin*, *albumen*, and *fibrin*—were introduced, at the author's suggestion, into the stomach through the fistulous opening in the subject of Dr. Beaumont's case; whilst other portions were digested *artificially* in gastric juice obtained from the same individual. The solutions presented the same appearance, and were similarly affected by reagents; and in all cases, whether the

[1] Bridgewater Treatise, Amer. edit., p. 235, Philad., 1834.

digestion was *artificial* or *real*, the proximate principles could be thrown down in the state of *gelatin*, *fibrin* or *albumen*, as the case might be. These experiments, so far as they went, justified the conclusion, that the digestive process in the stomach is a simple solution or division of alimentary substances, and an admixture with the mucous secretions of that organ, and the various fluids from the supra-diaphragmatic portion of the digestive tube. With regard to the existence of the other gastric operations described by Dr. Prout, well-founded doubts may be entertained. To his proposition that, whatever may be the nature of the food, the general composition and character of the chyle remain always the same, no objection can be urged; but, admitting its accuracy, it by no means follows, that the conversion must be effected in the stomach, or that any organizing or vitalizing powers are exerted upon the chyme in that organ. On the contrary, it appears that the essential changes effected on solid aliment in the stomach are of a purely physical character, so as to adapt it for the separation of the chylous portion in the intestines by organs whose vital endowments and influences cannot be contested. Dr. T. J. Todd[1] is disposed to believe, from his experiments on artificial digestion, that the various vegetable and animal substances subjected to the action of the digestive fluids at the ordinary temperature of the atmosphere are, in all instances, reduced—not to their *chymical*, but to their *organic* elements; and he is of opinion, that this applies equally to digestion in the stomach.[2]

From what has been already shown of the close approximation to each other in chemical composition of several of the compounds of organization, it may be understood, that many vegetable principles might be converted into animal principles without any material change of composition. They might all perhaps be changed into albumen, from which, as elsewhere seen, fibrin differs but little except in its organizable power. Saccharine matters—it has been conceived—may be converted, in the digestive tube, partly into albumen, and partly into oleaginous matter, the nitrogen of the former being furnished, according to some, by the pepsin or by some highly nitrogenized substance secreted in the stomach, or duodenum, or both;[3] but whether such conversion really occurs there is more than questionable. The oleaginous matters themselves are absorbed by simple imbibition as an emulsion formed by their union with the alkali of the pancreatic fluid.[4]

Most physiologists now agree, that animal food is converted into a modification of albumen, called *albuminose*,[5] which, when it enters the vessels, is more easily assimilated than albumen. Whilst a solution of the latter, indeed, if injected into the bloodvessels, is separated by the kidney; the former undergoes assimilation in the system of nutri-

[1] Brit. Annals of Medicine, Jan., 1837.

[2] See, on the action of the gastric juice on aliments, Beaumont, op. cit.; and Béraud, Manuel de Physiologie, p. 134, Paris, 1853.

[3] Prout, on the Stomach and Urinary Diseases, p. xxviii., note.

[4] Matteucci, Lectures on the Physical Phenomena of Living Beings, by Pereira, Amer. edit., p. 110, Philad., 1848, and C. Bernard, Archives Générales, xix. 60, cited in British and Foreign Medico-Chirurgical Review, p. 528, April, 1849.

[5] See page 48.

tion. On cane sugar a similar effect appears to be induced by admixture with the gastric secretions. It is converted into glucose, which when absorbed is more readily appropriated, or a portion of it may be converted into lactic acid.

On the whole, in the present state of our knowledge of this important function, we are perhaps justified in concluding:—*First.* That by the operation of the gastric secretions the nitrogenized principles of the food, whether animal or vegetable, are dissolved in the stomach. *Secondly.* That amylaceous matters are converted by the buccal secretions into saccharine, and these last are absorbed; or they undergo a farther change, by which they are partly converted into lactic acid, and partly into oleaginous matter [?]. *Thirdly.* That the oleaginous matters undergo no change in the stomach; and *Fourthly.* That with the exception of certain mineral substances, matters that cannot be reduced to either of these forms are sent on into the intestinal canal, to be rejected as excrement.

In proportion as the food is digested, it passes through the pylorus. After the layer, that lies next to the mucous membrane, has experienced the requisite change, and is propelled onwards by the muscular action of the organ, the portion lying next to it becomes subjected to the same process. The gastric fluid, at the same time, penetrates, in a greater or less degree, the entire alimentary mass, so that, when the central portion comes in contact with the surface of the stomach, its conversion is already somewhat advanced. The chyme, thus successively formed, does not remain in that organ, until the whole alimentary mass has undergone chymification; but as it is completed, it is transmitted, by the peristaltic action, through the pylorus into the duodenum. In the early stages of digestion, the passage of the chyme from the stomach is more slow than in the later. At first, it is more mixed with the undigested portions of food, and, as Dr. Beaumont[1] suggests, is probably separated with difficulty by the powers of the stomach. In the more advanced stages, as the whole mass becomes chymified, the process is more rapid, and is accelerated by the peculiar contraction of the stomach, already described. After the expulsion of the last particles of chyme, the organ becomes quiescent, and no more gastric secretion takes place, until a fresh supply of food is received, or some mechanical irritation is produced in its inner coat.

The time, required for the complete chymification of a meal, is stated by the generality of physiologists to be about four or five hours. In Dr. Beaumont's case,[2] a moderate meal of meat, with bread, &c., was digested in from three hours to three hours and a half. We believe that, in by far the majority of cases, a longer time than this is necessary; and in laborious digestions, the presence of food can be distinguished by eructations for more than double the time. It is manifest, that no fixed period can be established for the production of this effect. It must vary, according to the digestive capability of the individual; the state of his general health; and the relative digestibility of the aliments employed; all which, as we have already seen, admit of great diversity. It would seem that the most digestible aliments should be

[1] On the Gastric Juice, p. 96.

[2] Ibid., p. 275.

most speedily sent on into the duodenum; yet such is not perhaps the case. Certain it is, that many articles pass the pylorus after having experienced little or no change; and in cases of artificial anus, Professor Lallemand, of Montpellier, observed that the least nutritive and least digestible presented themselves first. Vegetable substances appeared before animal; and totally indigestible substances—as pieces of money—are known to clear the stomach rapidly.[1]

During chymification only a very small quantity of air is found in the stomach; sometimes, none. When met with, it is near the cardiac orifice, or at the upper part of the splenic portion. M. Magendie examined the gases in the stomach and intestines of executed criminals, and obtained the following results: *a*, in the case of an individual who had taken food in moderation an hour previous to death; *b*, in the case of one who had eaten two hours previously; and *c*, in the case of one who had done so four hours previous to execution.

		100 volumes of the gas contained			
		Oxygen.	Azote.	Carbonic Acid.	Inflammable Gas.
a	From the stomach,	11.00	71.45	14.00	3.55
	——— small intestines,	00.00	20.08	24.39	55.33
	——— large do.	00.00	51.03	43.50	5.47
b	From the stomach,	00.00	00.00	00.00	00.00
	——— small intestines,	00.00	8.85	40.00	51.15
	——— large do.	00.00	18.40	70.00	11.60
c	From the stomach,	00.00	00.00	00.00	00.00
	——— small intestines,	00.00	66.60	25.00	8.40
	——— large do.	00.00	45.96	42.86	11.18[2]

From these results it appears, that when the execution occurred not longer than an hour after a meal, oxygen was found in the stomach; and when not until two hours, it had entirely disappeared, and a large quantity of nitrogen was found in the intestines, with an entire absence of oxygen; whence it is inferred, that the oxygen of the air is separated from the nitrogen in the stomach; and the former is employed in digestion. The view of Liebig is, that the oxygen occasions a molecular action in the pepsin or animal matter in the stomach, and that this intestine motion is communicated to the molecules of the albumen or protein of the food, so that the latter is rendered soluble in the gastric acid.[3] The oxygen he refers to atmospheric air enclosed in the saliva during mastication, and in that way introduced into the stomach.

The small quantity of air, discovered in the stomachs of animals, disproves the idea of M. Chaussier, that we swallow a bubble at each effort of deglutition. If so, the stomach ought to be always inflated, especially after eating, which is not the case. MM. Leuret and Lassaigne[4] found the air, obtained from the stomach of a dog fed on meat, to consist of carbonic acid, 43 parts; sulphuretted hydrogen, 2 parts; oxygen, 4 parts; nitrogen, 31 parts; carburetted hydrogen, 20 parts. Whence these gases proceed will be a subject of future inquiry.

In a robust individual, chymification is effected without consciousness of the process. He finds, especially if the stomach be over-dis-

[1] Béraud, Manuel de Physiologie, p. 148, Paris, 1853.
[2] Liebig, op. cit., p. 289.
[3] Ancell, Lond. Lancet, Dec. 16, 1842, p. 419.
[4] Recherches sur la Digestion, Paris, 1825.

tended, that the feeling of fulness and the oppression of respiration, produced by the distension of the organ, gradually disappear. It is not uncommon, however, for slight shivering or chilliness to be felt at this time; for the sensations, and mental and moral manifestations to be blunted; and a disposition to sleep to be experienced. "This concentration of the whole vital activity," according to M. Adelon,[1] "is so natural to the animal economy, that there is always danger in opposing or crossing it by any extraneous or organic influence; as by bathing, the use of medicine, violent exercise, mental emotions, intense intellectual effort, &c." Gentle exercise, however, would seem to favour digestion. Such is the conviction of Dr. Beaumont,[2] from his observations. In the subject of his experiment, he found the temperature of the stomach generally raised by it a degree and a half, and chymification expedited. Where digestion is imperfect, the signs, already mentioned, will be accompanied by the disengagement of air and consequent eructations; a sense of weight, or of heat, or of unusual distension in the epigastric region, &c.; but these, as well as the developement of sulphuretted hydrogen, discharged by eructation, are the products of ordinary decomposition or fermentation, and appertain to the morbid condition of the function or to indigestion. Yet, as M. Magendie[3] has remarked, it does not seem, that these laborious digestions are much less profitable than others. The food, habitually received into the stomach, contains far more nutritive matter than is necessary to supply the wants of the system; and, in the cases in question, enough chyle is always separated in the small intestine to supply the losses, and even to add to the bulk of the body.

It has been already remarked, that the chyme, first formed, does not continue in the stomach until the whole meal has undergone chymification; but that, as soon as it has experienced the necessary changes, it passes through the pylorus into the duodenum. It would appear, that the accumulation of chyme in the pyloric portion of the stomach never exceeds four ounces at any one time. M. Magendie states, that, in the numerous experiments, in which he has had an opportunity of noticing it, he uniformly found, when the quantity amounted to about two or three ounces, it was permitted to pass through the pylorus into the duodenum. This passage of the chyme is effected by the peristaltic action. At the commencement of digestion, the duodenum contracts inversely, and the pyloric portion of the stomach, at the same time, drives its contents into the splenic. This movement is, however, soon followed by one in an opposite direction; and, after a time, the inverted action ceases, and the movement is altogether in one direction;—from the stomach towards the intestine. The movement by which the chyme is immediately sent into the duodenum, is thus effected:—the longitudinal fibres, which pass from the cardiac to the pyloric orifice, contract, and approximate the two orifices; the pyloric portion then contracts, not so as to direct the chyme into the splenic portion, but towards the duodenum: in this manner, the chyme passes from the stomach: and, as fresh portions are formed, they are success-

[1] Physiologie de l'Homme, edit. cit., ii. 433.
[2] On the Gastric Juice, p. 93.
[3] Précis, &c., ii. 104.

ively sent onwards; the peristaltic action becoming more and more marked and frequent, and extending over a larger portion of the organ, as chymification approaches its termination. As the chyme is discharged into the small intestine, the stomach gradually returns to its former dimensions and situation.

f. *Action of the Small Intestine.*

The changes in the alimentary mass in the small intestine are not less important than those already considered. They consist in a farther change of the chyme into a substance, whence *chyle* can be extracted by the action of the chyliferous vessels or lacteals. Whether chyle be separated in the intestine, in a state fit for chyliferous absorption, or be formed by those vessels, will have to be canvassed hereafter. In common language, however, it is said to be separated there, and the process, by which this is accomplished, is called *chylification.*

As the chyme proceeds into the duodenum, it readily finds space, until towards the end of chymification, when the intestine not unfrequently experiences considerable dilatation. The presence of the alimentary mass augments the secretion from the mucous membrane; and occasions a greater flow of the biliary and pancreatic juices. MM. Leuret and Lassaigne[1] found, when they applied vinegar, diluted with water, to the external surface of the small intestine in a living animal, that a considerable quantity of serous fluid was immediately exhaled. The same application, made to the follicles of the intestine, excited the secretion of a greater quantity of mucus; and its application to the mouths of the choledoch and pancreatic ducts caused the orifices to dilate, and a greater discharge of bile and pancreatic juice. It is in this local manner that many of the cholagogue purgatives produce their effect. Calomel exerts its agency on the upper part of the intestinal canal more especially; and the irritation it induces in the mucous membrane at the mouth of the ductus communis choledochus is propagated along the biliary ducts to the liver, the secretion of which is thus augmented—but not by any specific action exerted on the organ, as has been often imagined. As the chyme is acid, it induces the same effects on the follicles as the acid employed in the experiments of MM. Leuret and Lassaigne.

The chyme does not remain so long in the intestine as food does in the stomach. The successive arrival of fresh portions propels the first onwards; and the same effect is induced by the peristaltic action of the intestines—an involuntary, muscular movement of an irregular, undulatory, oscillatory or vermicular character, which consists in an alternate contraction and dilatation of the organ, proceeding generally from above to below, so as to propel the chyme downwards. When it reaches any point of the intestine, its contact excites the contraction of the circular fibres of the part; so that it is sent forwards to another portion of the canal; the circular fibres of which contract, whilst the former are relaxed; and this occurs successively through the whole tract of the intestines. The longitudinal fibres, by their contraction, shorten the intestine, and in this manner meet the chyme, so as to

[1] Recherches sur la Digestion, Paris, 1825.

facilitate its progress; but their effect cannot be considerable. When digestion is not going on, the peristaltic action occurs only at intervals; always slowly and irregularly; and perhaps, as has been suggested, only when sufficient mucous secretion has collected on the inner coat of the intestine to provoke it. During digestion, it is much more energetic and frequent, and more marked in the duodenum and small intestine than in the large; occurring not continuously, but at intervals, as the chyme arrives and excites it. When the small intestine is surcharged, it may take place in several parts of the canal at once; and, at times, the action is inverted.

The secretions poured into the intestinal canal lubricate it, and facilitate the progress of the chyme. This is aided by the free and floating condition of the intestine; and by the agitation of the diaphragm and abdominal muscles in respiration. Yet its course along the small intestine is slow. The chyme is not transmitted from the stomach continuously; and the peristaltic action of the intestines occurs only at intervals. Moreover, owing to the convolutions of the intestinal canal, the chyme must, in many cases, proceed against its own gravity; and be retarded by the numerous valvulæ conniventes, which bury themselves in it, when the canal is contracted by the action of the circular fibres. All these circumstances must cause it to proceed slowly along this part of the tube—a point of some importance, when we reflect, that an essential change is effected on it through the influence chiefly of the bile and pancreatic juice, and that its nutritive portion is here absorbed. In the duodenum, the course of the chyme is slow. In the jejunum it is more rapid, hence the name, which indicates, that it is almost always found "empty:" in the ileum again it is slower on account of the greater consistence acquired by the absorption of the chylous portion. Whilst the food is in progress along the small intestine, it experiences the change in its physical properties, which enables the chyle to be separated from it by absorption. These two actions have been termed respectively *chylification* and *the absorption of chyle;* although by some the former term has been applied to both processes.

Above the point at which the common choledoch and pancreatic ducts open into the duodenum, no change is observable in the chyme. It preserves its color, semi-fluid consistence, sour smell, and slightly acid taste; having been simply mixed with the exhaled and follicular secretions of the lining membrane; but, immediately after it has passed the part, at which the hepatic and cystic bile and the pancreatic juice are poured into the intestine, it assumes a different appearance; its color is found to be changed; it becomes yellowish; of a bitter taste; its sour smell diminishes; and chyle can now be separated by the lacteals. Accordingly, at this part of the canal, chyliferous vessels are first perceptible.

The change effected upon the chyme in the small intestine is,—like that produced on the food in the stomach,—of an entirely physical character. The chyle itself, we shall endeavour to show hereafter, is formed by an action of elaboration and selection exerted by the chyliferous vessels. No difference is observable between the chylous and excrementitious portions of the chyme in any part of the small intestine; nor can it be separated by pressure or by any other physical process. M. Magendie,[1] indeed, has affirmed, that if the chyme proceeds from animal or vegetable substances that contain fat or oil, irregular filaments are observed to form, here and there, on the surface,—sometimes of a flat, at others, of a round shape,—which speedily attach themselves to the surface of the valvulæ, and appear to be *brute chyle;* but this is not observed when the chyle proceeds from food, that does not contain fat. In this case, a grayish layer, of greater or less thickness, adheres to the mucous membrane, and appears to contain the elements of chyle. MM. Leuret and Lassaigne[2] state, that if an animal be opened while digestion is going on,—on the surface of the chyme, between the pylorus and the orifice of the ductus communis choledochus, a grayish-white, homogeneous, dense, fluid, and acid substance is perceived on the villi of the intestine. Neither of these, however, is *chyle.* It is merely the substance whence chyle is obtained by the action of the chyliferous vessels. The fact, mentioned by M. Magendie,—regarding the appearance of irregular filaments, when animal or vegetable substances, containing fat or oil, have been taken as diet,—has been the occasion of erroneous deductions of a pathological character. Frank[3] asserts, that he was requested to see a prince, who was attacked with epilepsy. His physician,—a respectable old practitioner,—assured Frank, that he could make his patient void thousands of filiform worms at pleasure. As he was unable to define either the genus or species of these worms,—the quantity of which, from his account, seemed to be prodigious,—Frank requested to be a witness of the phenomenon. The physician administered a dose of castor oil, which produced numerous evacuations, containing thousands of whitish filaments similar to small eels; but on an attentive examination of these pretended worms, they were found to consist entirely of the castor oil, in a state of fine division.

The alteration of the aliment in the small intestine is probably of a chemical nature; yet it has been conceived to be organic and vital. The same remarks are applicable here as were indulged upon the supposed organic and vital action of the stomach exerted in the formation of chyme. The agents of this alteration are:—the fluids secreted from the mucous membrane of the small intestine, and the biliary and pancreatic juices, aided by the temperature of the parts, and the peristole. Haller[4] was of opinion, that the first of these is a principal agent. Reflecting on the extensive surface of the small intestine, on the number of arteries distributed to the organ, and on the size of these arteries, that distinguished physiologist asserted, that the lining membrane of the intestine, at the time of chylification, secretes a juice, which he estimated at the enormous quantity of eight pounds in the twenty-four hours. To this he gave the name *succus intestinalis—succus entericus*—and assigned it as important a part in chylification as he attributed to the gastric juice in chymification. It is probable, however, that the fluids secreted by the mucous membrane of this portion of the canal resemble those of the rest of the

[1] Précis, &c., ii. 111.
[2] Op. citat.
[3] De Curandis Hominum Morbis Epitome, lib. vi. p. 218.
[4] Element. Physiol., xix. 5.

intestinal mucous membrane; and that a main function is that of lubricating the intestine, and of still further diluting the chymous mass. MM. Leuret and Lassaigne endeavoured to procure some of them by making animals, whilst fasting, swallow small sponges, enveloped in fine linen, and killing them twenty-four hours afterwards. Some of these sponges had not gone further than the stomach, and were filled with gastric juice; others, which had reached the small intestine, had imbibed the *succus intestinalis*, which was more yellow, and manifestly less acid than the gastric secretion. On attempting to dissolve a crumb of bread in each of these juices, they discovered that the gastric secretion communicated a sour smell to the bread; but that the intestinal secretion allowed the bread to be precipitated, and dissolved no part of it. From this experiment, it has been concluded, that the succus intestinalis is not a great agent in chylification. No weight, however, can be placed upon results obtained in so unsatisfactory a manner; for it is obvious, that no certainty could exist as to the identity between the gastric and intestinal juices and the fluids found in the respective sponges.

We have strong reason, indeed, for believing, that, even if food should escape the action of the stomach, it is capable of being digested in the small intestine. This may be owing to some of the true gastric juice passing into the intestinal canal, and impregnating it; or it may be a similar secretion from follicles seated there. Experiments by Bidder and Schmidt on living animals have shown, that albuminous matters inserted into the ileum, when all excess of gastric juice was prevented, were acted upon in the same manner as in the stomach; and Dr. C. H. Jones proved the correctness of their inferences, on repeating the experiments.[1] The lining membrane of the small intestine possesses the property of coagulating milk; and pathological cases occur in which the stomach is, to all appearance, completely disorganized; yet patients survive so long as to compel us to presume, that digestion must have been effected elsewhere than in that organ. M. Magendie[2] placed a piece of raw meat in the duodenum of a healthy dog. At the expiration of an hour it had reached the rectum, and its weight was found to be but slightly diminished; the only change appeared to be at its surface, which was discoloured. In another experiment, he fixed a piece of muscle with a thread, so that it could not pass out of the small intestine. Three hours afterwards, the animal was opened. The piece of meat had lost about half its weight. The fibrin was especially attacked; and what had resisted, which was almost all areolar tissue, was extremely fetid. In experiments by M. Voisin,[3] aliment was introduced into the small intestines of animals,—in one case masticated and mixed with saliva; in another without any preparation. In a few hours, in the first instance, and after a longer period in the second, the food was as completely chymified as if the process had taken place in the stomach. The same experiments were repeated upon animals whose pylorus had been secured by ligature, and with similar results. One of them lived for a month after the

[1] Th. K. Chambers, Brit. & For. Med.-Chir. Rev., Oct. 1855, p. 311.
[2] Précis, &c., ii. 113.
[3] Nouvel Aperçu sur la Physiologie du Foie, etc., Paris, 1833.

ligature, nourished for that period by food introduced into the duodenum. These facts sufficiently show, that a solvent action is exerted in the small intestine; and there is reason for ascribing to the mixed fluid poured into it a great power of reducing alimentary substances to a condition in which they may be absorbed. MM. Cl. Bernard and De Chaniac[1] found it act energetically on all alimentary principles; it emulsified fatty bodies; modified albuminous substances, and transformed starch into sugar; and Bidder and Schmidt are of opinion that in addition to the succus intestinalis exerting a solvent action on albuminous substances scarcely less than that of the gastric juice, it has a power of converting starch into sugar scarcely less than that of saliva or pancreatic fluid. Dr. Ayres,[2] indeed, from his "microchemical researches on the digestion of starch and amylaceous foods" is disposed to assign almost the whole action to the succus intestinalis, since he found the conversion into glucose to occur after the ligature of the common choledoch duct, and after the ligature of both the bile and pancreatic ducts in the same animal; and a farther proof was afforded of the activity of the intestinal mucus taken from the upper part of the duodenum, above the entrance of the pancreatic duct, after ligature of that duct and of the common bile-duct, by its capability of converting a large quantity of fresh-boiled starch into glucose out of the body.

The biliary and pancreatic juices are usually esteemed great agents in chylification. It has been already remarked, that the chyliferous vessels do not begin to appear above the part at which these juices are poured into the duodenum; that in the rest of the small intestine they are less and less numerous as we recede from the duodenum; and that the chyme does not exhibit any marked change in its properties, until after its admixture with those fluids. Direct experiments have been made for the purpose of testing the use of the bile in digestion. Sir Benjamin Brodie tied the ductus communis choledochus in young cats, so as to prevent both hepatic and cystic bile from reaching the intestine. He found, that chylification was interrupted, and there were neither traces of chyle in the intestines nor in the chyliferous vessels. The former contained only chyme, similar to that of the stomach, which became solid at the termination of the ileum; and the latter, a transparent fluid, which appeared to be a mixture of lymph, and of the more liquid portion of the chyme. Mr. Mayo,[3] likewise, found, that when the ductus communis choledochus was tied in the cat or dog, and the animals were killed at various intervals after eating, there was no trace whatever of chyle in the lacteals. M. Magendie,[4] however, repeated these experiments on adult animals, and with dissimilar results. The greater part died of the consequences of opening the abdomen, and of the operation required for tying the duct. But in two cases, in

[1] Art. Digestion, p. 231, in Supplément au Dictionnaire des Dictionnaires de Médecine, par Fabre, Paris, 1851; and Bidder and Schmidt, Die Verdauungssäfte und der Stoffwechsel, S. 272, Mitau und Leipzig, 1852. See also, Lehmann, Physiological Chemistry, Amer. edit. by Dr. R. E. Rogers, i. 512, Philad., 1855.

[2] Proceedings of the Royal Society; and Quarterly Journal of Microscopical Science, April, 1855, p. 251.

[3] Lond. Med. and Physical Journal, Oct., 1826; and Outlines of Physiology, 4th edit., p. 125, London, 1837.

[4] Op. citat., ii. 117.

which they survived some days, he discovered that digestion had persisted; white chyle had been formed, and stercoraceous matter produced. This last had not the usual colour; but this, as he remarks, is not surprising, as it contained no bile. The experiment was repeated by MM. Leuret and Lassaigne,[1] and with results similar to those obtained by M. Magendie. In the duodenum and jejunum, a whitish chyme adhered to the parietes of the organ; and in the thoracic duct there was a fluid of a rosy-yellow colour, which afforded, on analysis, the same constituents as chyle; although the subjects of the operation had been kept, for some time, without food.

The experiments of Messrs. Tiedemann and Gmelin[2] on this subject were marked by the usual care and accuracy of those observers. They found, that the animals were attacked with vomiting, soon after the operation, and afterwards with thirst and aversion for food; on the second or third day, the conjunctiva became yellow, the evacuations chalky, and very fetid, and the urine yellow. Some of the animals died; others were killed: of the latter, some had previously recovered from the jaundice, owing to a singular recuperative phenomenon, noticed by Dr. Blundell[3] and Sir B. Brodie in their experiments—to the re-establishment of the choledoch duct, by the effusion of lymph around the tied part, and the subsequent dropping off of the ligature. Like Sir B. Brodie, Mayo, Leuret and Lassaigne, and Voisin, they observed that chymification went on as in the sound animal.

The thoracic duct and chyliferous vessels, in animals fed a short time before death, always contained an abundant fluid, which was generally of a yellowish colour. It coagulated like ordinary chyle; the crassamentum acquired the usual red colour; and the only difference between it and the chyle of a sound animal was, that after tying the duct it was never white. They conceived the reason of the difference to be, that the white colour is owing to fatty matter taken up from the food by the agency of the bile, which possesses the power of dissolving fat; and may probably, therefore, aid in effecting its solution in the chyle in the radicles of the chyliferous vessels. Sir Benjamin Brodie and Mr. Mayo are considered to have been misled by the absence of the white colour, usually possessed by the chyle, but which is wanting in ordinary digestion, if the food does not contain fatty matter.[4] The experiments of Dr. Beaumont showed, that oil undergoes but little change in the stomach, and that bile is probably necessary to give it the requisite physical constitution, in order that chyle may be separated from it. Messrs. Tiedemann and Gmelin restrict the agency of the bile in chylification to the accomplishing of the solution of the fatty matter, and to the nitrogenizing or animalizing of food that does not contain nitrogen. The experiments of M. Voisin equally show, that the ligature of the choledoch duct does not prevent the formation of chyle, provided the passage of the pancreatic fluid is not at the same time prevented. In

[1] Recherches sur la Digestion, p. 147, Paris, 1825.

[2] Recherches Expérimentales, &c., sur la Digestion, ii. 53, Paris, 1827.

[3] Researches, Physiological and Pathological, London, 1825; and Elliotson's Physiology, p. 124, London, 1840.

[4] Edinb. Med. and Surg. Journal, xciii.; and Mayo, Outlines of Human Physiology, 4th edit., p. 139, London, 1837.

a number of dogs, a ligature was applied so as to completely prevent the passage of bile into the intestine. Two lived three months after the experiment: three, six weeks; and five died shortly after the application of the ligature. In no instance did death appear to be owing to the suspension of digestion or assimilation. Almost all the animals had begun to eat; and, in the majority, food perfectly chymified was found in the duodenum; and well elaborated chyle in the chyliferous vessels. It would appear, therefore, that the bile, although an important, is not an essential agent in digestion in the duodenum. This is signally corroborated by the cases of two infants, four or five months old, recorded by Dr. Blundell. The hepatic ducts in both cases terminated blindly, so that no bile entered the intestines; the evacuations were white like spermaceti, and the skin jaundiced. Yet they grew rapidly, and throve tolerably.

No certain knowledge exists, whether any of the elements of the bile are absorbed in the form of chyle; or whether it acts mainly as a precipitate, and is thrown off with the excrement. As elsewhere shown, however, it is largely excrementitious or depurative.

As to the mode in which the biliary and pancreatic fluids act on the chyme, we have not had, until recently, much more than conjectures to guide us. MM. Tiedemann and Gmelin suggest, that the soda of the bile unites with the chlorohydric and acetic acids of the chyme; and simultaneously the latter precipitates the mucus of the bile and its colouring principle and resin, which are evacuated with the excrements. The majority of physiologists believe, that bile is divided into two parts by the action of the chyme; the one—containing the alkali, salts, and a part of the animal matter—uniting with the chyle; the other—containing the coagulated albumen, the coloured, concrete, acrid, and bitter oil—uniting with the fæces, to be discharged along with them. According to this view, the action of the bile would be purely chemical; a part would be recrementitial or taken up again; and a part excrementitial, giving to the excrements their smell and colour; and, according to some, the necessary stimulating property for exciting the flow of the intestinal fluids, and soliciting the peristaltic action of the intestines so as to produce their evacuation. It is more than doubtful, however, whether the bile have any such influence as the last. It is a law in the economy, that no secretion irritates the part over which it passes, or is naturally destined to pass, unless such part is in a morbid condition; and were it otherwise, the mucous membrane of the intestine would be soon accustomed to the stimulation; and, the effect be null. MM. Tiedemann and Gmelin further suggest, that from the abundance of highly nitrogenized principles, which the bile contains, it probably contributes to animalize those articles of food, that do not contain nitrogen; and that it may tend to prevent the putrefaction of the food in its course through the intestines, inasmuch as when it is prevented from flowing into them, their contents appear much farther advanced in decay than in the healthy state. M. Bernard,[1] too, has shown experimentally, that in the living body

[1] Amer. Journ. of the Med. Sciences, Oct. 1851, p. 351.

it checks the process of fermentation, which it had been found to do out of the body.

It has been held of late, that bile has the power of transforming saccharine aliments into fat; a circumstance, which is favoured by the discovery of H. Meckel,[1] that when sugar is mixed with bile out of the body a part of it is converted into fatty matter. Admixture with the pancreatic juice would then render its absorption easy. (See SECRETION OF BILE.)

We were not instructed until of late in regard to the precise uses of the pancreatic juice; although many have been assigned to it, which, being founded in ignorance of its nature and properties, it would be a waste of time to notice. Messrs. Tiedemann and Gmelin affirm, that it yields to the chyme the richly nitrogenized principles, that enter into its composition; and, consequently, aids in assimilation. In testimony of this, they remark, that the pancreas is larger in herbivorous than in carnivorous animals; and that, in proportion as the chymous matter proceeds along the intestinal canal, it exhibits itself less rich in albumen and other nitrogenized matters, which have probably been abstracted from it by absorption. Dr. Marcet[2] discovered in the chyme of the small intestine a notable developement of albumen, which was first perceptible a few inches from the pylorus, and did not exist in the large intestine; and Messrs. Tiedemann and Gmelin found in the intestinal contents of animals, that had swallowed pebbles while fasting, more albumen than the pancreatic juice could account for. If such be the fact, albumen must be either developed from the food, or secreted from the mucous membrane.

There is a striking resemblance in chemical properties between the pancreatic juice and saliva; and the views applicable to both one and the other, embraced, as the result of numerous experiments by MM. Bernard and Barreswil, have been already stated. The experiments of M. C. Bernard[3] have shed important light on this matter. Exposure of fatty bodies to the pancreatic juice out of the body produced at once a complete emulsion, whilst no such effect was produced on such bodies by admixture with other fluids—saliva, gastric juice, or serum of the blood, for example. These experiments were frequently repeated with like results in the presence of distinguished observers—MM. Magendie, Bérard, Andral, &c. When dogs to which fatty substances had been given were killed during digestion, these substances were found unaltered until they came in contact with the pancreatic fluid; and if the duct of the pancreas was tied all change was prevented. It would seem, therefore, that although the pancreatic fluid resembles the saliva in many respects—so much so, indeed, that the pancreas has been styled "the abdominal salivary gland,"—it is possessed of properties as a digestive fluid which the saliva has not. In

[1] Henle und Pfeuffer, Zeitschrift fur rationelle Medicin; cited by Mr. Paget in Report in British and Foreign Medical Review, p. 261, July, 1846.

[2] Medico-Chirurgical Trans., vi. 618.

[3] Archives Générales, xiv.; translated in the Provincial Medical and Surgical Journal for March 31, 1849. For an account of M. Bernard's investigations, see Dr. Donaldson in Amer. Journ. of the Med. Sciences, Oct. 1851; and H. Ludlow, Brit. and For. Med.-Chir. Rev., Jan. 1854, p. 62.

a remark upon a subsequent mémoire by M. Bernard—the commission, consisting of MM. Magendie, Milne Edwards and Dumas—do not hesitate to conclude, that M. Bernard has completely established the physiological office of the pancreas and made known the mechanism of the digestion of fatty matters.[1] It has been shown, however, by the experiments and observations of Frerichs,[2] Lehmann, Lenz, Herbst[3] and others, that digestion of fatty matters takes place after the pancreatic duct has been tied—sufficient time having been permitted for the evacuation of any pancreatic fluid, which may have been in the intestine prior to the operation—and even in the lower portion of the small intestine, into which these substances have been conveyed by injection after entire isolation, by means of a ligature, from the part of the canal into which the pancreatic secretion had been discharged. It would seem, too, from the results of the experiments of those observers, that a mixture of the fluid of the pancreas with bile and the succus intestinalis has a greater emulsifying power than the first of these fluids alone. The succus intestinalis would seem, indeed, to be an important adjuvant in the action.[4]

The influence of the temperature of the interior of the intestine, and of the peristaltic motion, on chylification, can be looked upon as only accessory and indirect.

Whilst the chyme is passing through the small intestine, it is subjected to the action of the chyliferous vessels, which extract from it the nutritious part or *chyle*,—a fluid especially destined for the renovation of the blood. How this is accomplished will be treated of under the head of Absorption. In proportion as this absorption is effected, the chyme changes its properties. In the commencement of the jejunum, it is the same as in the duodenum; but, lower down, the grayish layer, that existed at its surface, is observed to gradually disappear. It assumes greater consistence; its yellow colour becomes more marked; and, in the ileum, it has a greenish or brownish tint; and from being acid becomes alkaline, until, at the lower part of the small intestine, it seems to be the useless residue of the alimentary matter, and of the various secretions from the upper portion of the digestive apparatus. It is now mere excrementitious matter or fæces, although not possessing the entire fæcal odour. Its alkaline character has generally been ascribed to admixture with the bile, pancreatic fluid, and the secretion from the intestinal glandulæ. The agency of the bile was supposed to be through its free soda, or the carbonate or tribasic phosphate of soda. The bile, however, as shown elsewhere, is neutral; and accordingly it has been suggested as more probable, that the chyme is made alkaline by the ammonia, which is one of the

[1] Gazette Médicale, No. 9, Paris, 1849.

[2] Wagner's Handwörterb. der Physiologie, art. Verdauung, 3ter Band, S. 845, Braunschweig, 1846; and Bidder and Schmidt, Die Verdauungssäfte und der Stoffwechsel, S. 246, Mitau und Leipz., 1852.

[3] Henle and Pfeuffer's Zeitschrift, Bd. iii., S. 389–91; and Canstatt's Jahresbericht, 1853, S. 148, Würzburg, 1854.

[4] Todd and Bowman, The Physiological Anatomy and Physiology of Man, Pt. iv., Sect. 1, p. 246, Lond., 1852; and Prof. S. Jackson, Amer. Journ. of the Med. Sciences, Oct. 1854, p. 307.

products of the spontaneous decomposition of bile in the intestines.[1] The pancreatic juice is certainly alkaline.

During the formation of chyle, gases are almost always present in the small intestine. They were first examined by Jurine; but chemical analysis was by no means as advanced at that day as it is now; MM. Magendie[2] and Chevreul have more recently analyzed those, which they found in the small intestines of three criminals; all young and vigorous. The results of this analysis have been given already (p. 174). The gases might originate in various ways. They might pass, for example, from the stomach with the chyme. There is this objection, however, to the view; that the air in the stomach contains oxygen and very little hydrogen; whilst a considerable quantity of the latter gas is almost always found in the small intestine, and never oxygen. Again, they might be secreted by the mucous membrane of the intestine. So far as we know, however, carbonic acid and nitrogen are alone exhaled from the tissues. We would still have to account for the hydrogen. Lastly, they might arise from the reaction of the elements of the chyme upon each other, and this has been considered the most probable origin. M. Magendie[3] has frequently seen bubbles of gas escaping from the chymous mass, between the mouth of the ductus communis choledochus and the ileum; but never from that of the ileum, the upper part of the duodenum, or stomach; and he affirms, that Chevreul, in prosecuting some experiments, found that when the mass obtained from the small intestine was suffered to ferment for some time in a stove, at the temperature of the body, the same gases were obtained as those met with in the small intestine. The presence of air in the intestines has its positive advantages. It preserves the canal in a condition adapted for the ready exercise of its functions:—thus, it facilitates the progress of the contained matters, as it is more easy for the intestine, when it contracts, to propel substances contained in a hollow space, than in a canal whose sides are in contact.[4] The absorption of chyle is, doubtless, also favoured by it.[5]

When the food has attained the lower part of the ileum, the process of chylification has been accomplished, and the residuary matter is transmitted, by the peristaltic action, into the large intestine. The movement, however, recurs irregularly and at long intervals. In the living animal it can rarely be perceived; but may be noticed in one recently killed, and appears to have no coincidence with that of the pylorus.

g. *Action of the Large Intestine.*

The large intestine acts as a reservoir and excretory canal for the fæces. The residue of the alimentary matter is sent on through the valve of Bauhin by the peristaltic action of the ileum. This valve, we have seen, is so situate at the point of union between the ileum and cæcum as to permit a free passage from the former to the latter, but to

[1] Valentin, Lehrbuch der Physiologie des Menschen, i. 338, Braunschweig, 1844.
[2] Précis, ii. 115. [3] Ibid., 117.
[4] Bérard, Manuel de Physiologie, p. 217, Paris, 1853.
[5] Körnback, De Necessitate Aëris Atmosphærici ad Sorbitionem Chyli Adjuvandum, Hal., 1848; cited in Thomas, Die Physiologie des Menschen, p. 281, Leipzig, 1853.

prevent return. The chymous mass is sufficiently soft to pass readily; and the quantity of mucus poured out from the lining membrane facilitates its course. When it has reached the large intestine, it first accumulates in the cæcum, which—being cellular or pouched like the colon—necessarily detains it for some time. In proportion, however, as the cæcum becomes filled, the peristaltic action is extended from the small intestine, and the matter is sent into the colon, the cells of which are successively filled; first, those of the ascending, and then those of the transverse and descending colon, as far as the annulus or commencement of the rectum. The whole of its progress through the large intestine is slowly accomplished. Independently of the pouched arrangement, which retards it, a part of the colon ascends, so that the fæcal matter must often proceed contrary to gravity. It becomes, moreover, more and more inspissated in its progress towards the outlet; and the peristaltic action recurs at greater intervals than in the upper portions of the tube. The importance of such a reservoir as the large intestine is obvious. Without it, we should be subjected to the inconvenience of evacuating the fæces incessantly.

Before the excrementitious matter reaches the lower portion of the small intestine, it has not the full fæcal odour; but acquires it after having remained there for a short time. The brownish-yellow hue becomes deeper; but its consistence, smell, and colour, vary considerably, according to the character of the alimentary matter; the mode and degree in which chymification and chylification have been accomplished; the habit of the individual, &c. &c. The fæcal matter, as we find it, consists of the excrementitious part of the food, as well as of the juices of the upper part of the canal, that have been subjected to the digestive process; of the secretions, poured out from the lower part of the intestine, and also, of substances, that have escaped the digestive actions of the stomach and small intestine, and are often perceptible in the evacuations. The peculiar fæcal impregnation is probably mainly dependent upon a secretion from appropriate follicles; and we can thus understand, if we take into consideration the digestion of the different secretions, why fæcal evacuations may exist, when the individual has not eaten for some time, or taken but little nourishment. Professor Bérard,[1] however, is of opinion, that it is the bile, more than any other liquid poured into the intestine, which gives the excrements their special characters, and especially the fæcal odour, and Leuret and Lassaigne had already remarked, that if bile be heated, it gives off a fæcal smell.

Some physiologists have believed, that chylification takes place even in the large intestine, and that chylous absorption is more or less effected there. M. Viridet[2] asserted, that the cæcum is a second stomach, in which a last effort is made to separate from the food the digestible and soluble portions it may still contain. In herbivorous animals, according to him, an acid solvent is secreted in it. MM. Tiedemann and Gmelin seem to admit the fact; and likewise think, that the fluid, secreted by the inner membrane of the intestine, assists

[1] Cours de Physiologie, ii. 373, Paris, 1849.
[2] Tractatus Novus de Primâ Coctione, &c., Genev., 1691.

in the assimilation of the food by means of the albumen it contains, and that fæcal matter is formed there. From various experiments instituted by Professor Schultz,[1] of Berlin, he infers, that the food in the cæcum becomes not only a second time sour, but that the acid chyme is there neutralized by the access of bile in the same way as in the duodenum. M. Blondlot,[2] however, states, that in many herbivorous animals and granivorous birds, as sheep, goats, pigeons and chickens, the contents of the cæcum were never acid unless sugar in some form had been mixed with their food. The acidity of the cæcum which then ensues, he thinks is the result of that part of the starch or sugar, which had not been absorbed in the small intestine, being transformed into lactic acid. The fact of the separation of chyle in the cæcum and colon is proved by the experiments of M. Voisin,[3] which consisted in introducing food into these intestines after the ileo-cæcal valve had been closed by ligature.

The physical characters of the fæces have been already described. When extruded, they have the shape of the large intestine, or of the aperture, through which they have been evacuated. If the form of either of these be modified, that of the excrement will be so likewise. In stricture of the colon—especially about the sigmoid flexure—and of the rectum, the fæces are squeezed through the narrowed portions, and often evacuated in the shape of ribands. The biliary secretion appears to modify the appearance of the fæces greatly. If, as in jaundice, it be prevented from flowing into the intestine, they are clay-coloured. M. Adelon[4] affirms, that, under such circumstances, they are more frequent. This is not the result of our experience, nor does it appear to be deduced from his own; as, a few pages before, he remarks, "it is certain, that if the bile does not flow, the excrements are dry, devoid of colour, and there is constipation." On the other hand, if the bile flows in too great quantity the fæces are darker coloured. It is doubtful, whether the varying quantity of the biliary secretion have much influence on the number of evacuations, unless the canal, through which it has to pass, is in a morbid condition. Many of the appearances in the fæces, which are conceived to be owing to a morbid condition of the biliary secretion, are the effect of admixture with products of morbid changes in the stomach or intestines. In elucidation of this, it may be observed, that the green evacuations of children are often referred to some pathological condition of the biliary secretion; whereas the colour is commonly owing to unusual formation of acid in the stomach, the admixture of which with healthy bile produces the colour in question.

The chemical properties of the fæces have been repeatedly inquired into. They must, of course, vary according to the nature of the food, its quantity, the kind of digestion, &c. Human fæces were examined by Rawitz[5] after animal and vegetable food had been taken. But few

[1] London Med. and Surg. Journ., Oct. 31, 1835; cited in American Journal of the Medical Sciences, Nov., 1836, p. 203.

[2] Traité Analytique de la Digestion, p. 103, Paris, 1844.

[3] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.

[4] Op. citat.

[5] Ueber die Einfachen Nahrungsmittel, Breslau, 1846, cited by Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 176, Philad., 1853.

fragments of muscular tissue were met with; but the cells of cartilage and fibro-cartilage—excepting those of fish—were found unchanged. Elastic fibres and fatty matters, which had escaped absorption, appeared to be unchanged; for fat cells were sometimes unaltered in the fæces; and crystals of cholesterin might generally be obtained from them, especially after the use of pork fat as diet.

Of vegetable aliments, large quantities of cell membrane were unaltered; and starch cells were commonly deprived of only part of their contents; the green colouring matter—chlorophyll—was unaffected, and the walls of sap vessels and spiral vessels were usually found in large quantities in the fæces,—their contents having been probably removed during digestion.

The average quantity of fæcal matter discharged by the adult in the twenty-four hours, has been estimated at about five or six ounces.[1] Wehsarg,[2] indeed, makes it less than this. The mean of seventeen observed cases was not much more than four ounces; so that if, according to the diet-scale of the Navy of the United States,[3] forty-five ounces of solid food are taken in the twenty-four hours, about forty ounces must be appropriated by the system daily. The discharged five ounces of fæces consist, almost wholly, of substances that are rebellious to the action of the gastric and intestinal secretions. It is estimated, that as much as seventy-five per cent. of the fæces is water, so that the solid matter in them is not, probably, more than an ounce, or an ounce and a half.

The fæces differ in each animal species. Those of the herbivora contain less animal matter than those of the carnivora and omnivora; and the agriculturist is well aware, that the excrements of all animals are not equally valuable as manure. The dung of the pigeon is alkaline and caustic; and hence has been employed in tanning for softening skins. The excrement of dogs, that have fed only on bones, is white, and appears to be almost wholly composed of the earthy matter of bone. It has not, however, been examined by modern chemists. This white excrement is the *album græcum*, *cynocoprus*, *spodium Græcorum*, *album canis* or *stercus caninum album*, of the older writers. It was formerly employed as a discutient in quinsies, and as an anti-epileptic agent, but is now justly discarded.

M. Vauquelin,[4] on comparing the nature and quantity of the earthy parts of the excrements of fowls with those of the food on which they subsisted, arrived at some results that are of interest to the physiologist. He found that a hen devoured, in ten days, 1111·843 grains troy of oats. These contained of phosphate of lime 136·509 grains; and of silica 219·548 grains; in the whole 356·057 grains. During these ten days she laid four eggs, the shells of which contained 98·779 grains of phosphate, and 58·494 grains of carbonate of lime; and

[1] Todd and Bowman, Physiological Anatomy, &c. Pt. iv. Sect. i. p. 267, Lond. 1852; and Budge, Memoranda der Speciellen Physiologie des Menschen, 5te Auflage, S. 99, Weimar, 1853.

[2] Mikroskopische und Chemische Untersuchungen der Fæces Gesunder Erwachsener Menschen, Giessen, 1853; and Scherer in Canstatt's Jahresbericht, 1853, S. 121; see, also, Ehring, ibid.; and Marcet, Proceedings of the Royal Society, June 15, 1854.

[3] See page 119.

[4] Annales de Chimie, tom. xxix. p. 3.

passed 185.266 grains of silica. The fixed parts, thrown out of the system during the time, consisted of:—

Phosphate of lime,	274·305 grains.
Carbonate of lime,	511·911
Silica,	185·266
Given out,	971·482
Taken in,	356·057
Surplus,	615·425

The quantity of fixed matter, therefore, given out of the system in ten days, exceeded the quantity taken in by this last amount.

The phosphate of lime, taken in, amounted to	136·509 grains.
That given out, to	274·305
	137·796

There must, consequently, have been formed 137.796 grains of phosphate of lime, besides 511.911 grains of the carbonate. The inferences, deduced from these experiments, were, that lime, and perhaps also phosphorus, is not a simple substance, but a compound formed of ingredients that exist in oats, water, or air; the only substances to which the fowl had access; and that silica must enter into its composition, as a part had disappeared. Before, however, we adopt these conclusions, the experiments ought to be repeated more than once. The chicken should be fed on oats some time before the excrements and shells are subjected to analysis; as the carbonate of lime, and the excess of phosphate detected on analysis, might have proceeded, not only from the food, but from earthy matters previously swallowed. Care should also be taken, that it has no access to any calcareous earth; and we must be certain, that it has not diminished in weight; as, in such case, the earth may have been supplied from its own body. These precautions are the more requisite, seeing, that experiments have shown, that certain birds cannot produce eggs unless they have access to calcareous earth.

There are some very remarkable instances of chemical changes, in mysterious actions more immediately concerned in the decomposition and renovation of the frame; or, in what has been abstractedly termed—the function of nutrition. Dr. Henry[1] has announced, that the following substances have been satisfactorily proved to exist in healthy urine;—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatin, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluoride of calcium, chloride of sodium, phosphate of soda, phosphate of ammonia, sulphur, and silex;—yet we have no proof that these substances are obtained from any other source than the food; and some of them are with difficulty obtained any where. Every one of them is necessary for the constitution of the urine; and many must be formed by a chemical union of their elements under the vital agency. Some are met with in the animal body exclusively.

[1] Elements of Chemistry, 9th edit., ii. 435, Lond., 1823.

Berzelius[1] found, in 100 parts of human fæces:—water, 73·3; unaltered residue of animal and vegetable substances, 7·0; bile, 0·9; albumen, 0·9; peculiar extractive matter, 2·7; substance, formed of altered bile, resin, animal matter, &c., 14; salts, 1·2. Seventeen parts of these salts contained, of carbonate of soda, 5; chloride of sodium, 4; sulphate of soda, 2; ammoniaco-magnesian phosphate, 2; phosphate of lime, 4. The excrements have likewise been examined by MM. Leuret and Lassaigne, and others; but none of the analyses have shed much light on the physiology of digestion. Analyses of the ashes of firm human fæces by Enderlin[2] yielded the following results:—chloride of sodium and alkaline sulphate, 1·367; tribasic phosphate of soda, 2·633; phosphate of lime, and phosphate of magnesia, 81·272; phosphate of iron, 2·091; sulphate of lime, 4·56; silica, 7·97.

In the large intestine, gases are met with, along with the fæces. These were examined by MM. Magendie[3] and Chevreul in the three criminals already referred to (page 174). The results accord with those of Jurine,[4] obtained long ago, as regards the nature of the gases; but they do not correspond with what he says relating to the carbonic acid, the quantity of which, according to him, goes on decreasing from the stomach to the rectum. The analyses of MM. Magendie and Chevreul show, that the proportion instead of decreasing, increases. Concerning the origin of these gases, the remarks made on those in the small intestine are equally applicable here. Marchand made two analyses of air discharged from the rectum. These yielded carbonic acid, 44·5 and 36·5; nitrogen, 14·0 and 29·0; hydrogen, 25·8 and 13·5; carburetted hydrogen, 15·5 and 22·0; and sulphuretted hydrogen, 1.[5]

When the fæcal matter has accumulated to the necessary extent in the rectum, its expulsion follows; and to this function the term *defecation* has been assigned. The fæces collect gradually in the large intestine, without any consciousness on the part of the individual. Sooner or later, the desire or want to evacuate them arises. This is usually classed among the internal sensations or desires. It is, however, of a mixed character. It is not always in a ratio with the quantity of fæces, as is shown by the fact, that occasionally the intestine is filled without the want arising; and, if they be unusually thin or irritating, the desire is developed, when an extremely small quantity is present,—as in cases of tenesmus. The period, at which the desire returns, is variable, according to the amount and character of the food employed, as well as the habit of the individual. Whilst the generality of persons evacuate the bowels at least once a-day,—and this at a period often regulated by custom,—others pass a week or two without any alvine discharge, and yet may be in perfect health. Nay, some of the collectors of rare cases[6] have affirmed, on the authority of Rhodius, Panarolus, Salmuth, and others, that persons may remain in health,

[1] Traité de Chimie, trad. par Jourdan et Esslinger, tom. vii., and Simon's Animal Chemistry, Sydenham Society edit., ii. 372, Lond., 1846, or Amer. edit., Philad., 1846.

[2] Annalen der Chemie und Pharmacie, Mars, 1844, cited by Mr. Paget, Brit. and For. Med. Rev., Jan. 1845, p. 277.

[3] Précis, &c., ii. 126.

[4] Mémoir. de la Soc. Royale de Méd., x. 72.

[5] Rudolph Wagner's Lehrbuch der Speciellen Physiologie, 1ste Lieferung, S. 228, Leipz., 1854.

[6] Art. Cas Rares, in Dict. des Sciences Médicales.

with the bowels moved not oftener than once a month, three months, half a year, two years, and even seven years! Sir Everard Home[1] refers to the case of General Grose, who was in the Dutch service, under the Duke of Cumberland, in the Flanders war; and who for thirty years had no passage through the bowels. General Gage noticed that he ate heartily; but in two hours left the table and rejected his meal. He was healthy, and capable of exercise like other men. Dr. Heberden[2] mentions the case of a person, who had naturally an evacuation once a month only; and another who had twelve evacuations every day during thirty years, and then seven every day for seven years, and grew fat rather than otherwise. A young lady, referred to by M. Pouteau,[3] had no evacuation for upwards of eight years; although during the last year she ate abundantly of fruit, and drank coffee, milk, tea, and broth with yolks of eggs; but she had copious greasy sweats;—and many similar extraordinary cases have been recorded by Dr. Chapman[4] of Philadelphia. When the desire to evacuate has once occurred, it generally persists until the fæces are expelled. Sometimes, however, it disappears and recurs at an uncertain interval; and, if again resisted, may become the source of pain, and ultimately command implicit obedience. That the pressure and irritation of the fæces develope the sensation is evidenced by the fact, that the momentary relief experienced at times, when the desire is urgent, is usually accompanied by a manifest upward return of the fæcal matters from the sigmoid flexure into the colon.

In evacuating the fæces, the object to be accomplished is,—that the contents of the large intestine shall be pressed upon with a force superior to the resistance presented by the annulus or upper extremity of the contracted rectum, and the muscles of the anus. The contraction of the rectum is generally insufficient to effect this last object, notwithstanding the great thickness of its muscular layer. In cases, however, of irritability of the rectum, the sphincter is incapable of resisting the force developed by the proper muscular fibres of the gut. Under ordinary circumstances, the aid of the diaphragm and abdominal muscles is invoked, and it is chiefly through these muscles, that volition influences the act of defecation,—suspending, deferring, or accelerating it, as the case may be. After a full inspiration, the muscles that close the glottis; and the expiratory muscles,—especially those of the anterior part of the abdomen,—contract simultaneously. The air cannot escape from the lungs; the diaphragm is depressed upon the abdominal viscera, and the whole thorax presents a resisting body; so that all the expiratory power of the muscles bears upon the viscera, and presses them against the vertebral column. In this way, considerable force is exerted upon the contents of the colon and rectum; the resistance of the sphincter,—already diminished by the direct exercise of volition,—is surmounted; it yields, and the fæces are extruded. The levator ani and ischio-coccygeus, aided by the transversus perinei muscle, support the anus during the expulsory efforts, and restore it

[1] Lect. on Comp. Anat., v. 12, Lond., 1828. [2] Commentarii, p. 14.
[3] Œuvres Posthumes, i. 27, Paris, 1783.
[4] Lectures on the more important Diseases of the Thoracic and Abdominal Viscera, p. 294, Philad., 1844.

to its place after the efforts have ceased. Astruc maintained, that the abdominal muscles had nothing to do with the act of defecation, which gave occasion to the jocose remark of Pitcairn,[1]—"Mihi videtur Astruccium nunquam cacasse alioquin sensisset musculos abdominis et se contrahere et alia exprimere posse."

Whilst *straining* is effected by the diaphragm and abdominal muscles, the longitudinal muscular fibres of the rectum contract, so as to shorten the intestine, and, consequently, the space over which the fæces have to pass. At the same time, the circular fibres contract from above to below, so as to propel the excrement downwards, and to cause the mucous membrane to extrude, and form a ring or *bourrelet*, like that which occurs at the cardiac orifice of the stomach, when the food is passing from the œsophagus into that organ. If this extrusion occurs to a great extent, it constitutes the disease called *prolapsus ani.*

Dr. O'Beirne,[2] of Ireland, guided by the following facts and arguments;—that great irritation would be produced in the sphincter ani, and bladder, if the fæces descended readily into the rectum;—that the difficulty experienced in throwing up an injection is inconsistent with the idea of the gut being open, and proves that it is firmly contracted and closed;—that when the surgeon has occasion to pass his finger up the rectum, he rarely encounters either solid or fluid fæces;—that the two sphincter muscles of the anus are weakened in certain diseases, and divided in operations, and yet it rarely happens, that the power of retaining the fæces is destroyed;—that on passing a stomach-tube to the height of half an inch up the rectum, in a number of healthy persons, it was found, that nothing escaped, and that the tube could be moved about freely in a space, which, on introducing the finger, was ascertained to be the pouch of the rectum; but that from the highest part of the pouch to the upper extremity of the gut—generally a distance of from six or seven to eight inches—it could not be passed upwards without meeting with considerable resistance, and without using a degree of force to mechanically dilate the intestine, which was plainly felt to be so contracted as to leave no cavity for this extent;—that when the instrument reached, in this way, the highest point of the rectum, the resistance to its passage upward was felt to be sensibly increased, until, at length, by using a proportionate degree of pressure, it passed rapidly forward, as if through a ring, into a space in which its extremity could be moved with great freedom, and as instantly a rush of flatus, of fluid fæces, or of both, took place through the tube;—and that in every instance, where the tube presented the least appearance of fæces after being removed, this appearance was confined to that portion which had entered the sigmoid flexure:—guided by these and other facts, Dr. O'Beirne concluded, that in the healthy and natural state, all the part of the rectum above its pouch is at all times, with the single exception of a few minutes previous to the evacuation of the bowels, firmly contracted, and perfectly empty, at the

[1] Opuscula medica (Lector) Roterodam, 1714.

[2] New Views of the Process of Defecation, &c., Dublin, 1833; reprinted in this country, Washington, 1834.

same time that the pouch itself, as well as the sigmoid flexure of the colon, is always more or less open, and pervious,—and that the sphincter ani muscles are but subsidiary agents in retaining the fæces. When the fæces are firm, considerable muscular effort is necessary to expel them; but when they are of a softer consistence, the contraction of the rectum is sufficient.

The sphincters—as elsewhere shown—afford examples of reflex action. After sensation and volition are suspended, they contract under direct irritation. Yet, like the respiratory muscles, they are of a mixed character,—partly voluntary and partly involuntary. They are involuntary, but capable of being aided or impeded by a voluntary effort. The state of gentle contraction, in which they constantly are, is evidently dependent upon their connexion with the spinal cord; for the experiments of Dr. Marshall Hall have exhibited, that it ceases, when the connexion is destroyed.

Air, contained in the intestinal canal, readily moves about from place to place, and speedily reaches the rectum by the peristaltic action alone. Its expulsion, however, is commonly accomplished by the aid of the abdominal muscles; when it issues with noise. If discharged by the contraction of the rectum alone, it is generally in silence. Children are extremely subject to flatulence; in the adult it is not so common. Certain kinds of diet favour its production more than others, especially in those of weak digestive powers, of which condition its undue evolution is generally an indication. The leguminous and succulent vegetables in general belong to this class. Where digestion is tardily accomplished, they give occasion to the copious disengagement of gas. Too often, however, the disgusting habit of constantly discharging air streperously from the bowels is encouraged, rather than repressed; and there are persons, who are capable of effecting the act almost as frequently as they attempt it.

The noise, made by the air, as it passes backwards and forwards in the intestinal canal, constitutes the affection called *borborygmus*.

So much for the digestion of solid food. In so delicate and complicated an apparatus, it would seem, that mischief ought more frequently to result from the various heterogeneous substances that are received into the digestive tube. Its resistance, however, to morbific agencies is astonishing. In the Museum of the Boston Society for Medical Improvement[1] an open penknife is preserved, which was swallowed by a child between three and four years of age, and passed from the bowels after the expiration of fifty-one hours; the child, in the meantime, playing about as usual, and not seeming to suffer. The story of the lunatic, under the care of Dr. Fox of Bristol, who swallowed "some inches" of a poker, which came away without any suffering, is regarded as authentic;[2] and there is no question in regard to the authenticity of the case of the sailor recorded by Dr. Marcet,[3] who swallowed a num-

[1] J. B. S. Jackson, A Descriptive Catalogue of the Anatomical Museum of the Boston Society for Medical Improvement, p. 158, Boston, 1847.

[2] Southey, The Doctor, iv. 297, Lond., 1837.

[3] Medico-Chirurgical Transactions, xii. 52, Lond., 1822.

ber of clasp knives with impunity, but ultimately fell a victim to his idle temerity,—having swallowed, in the whole, thirty-seven!

5. DIGESTION OF LIQUIDS.

In inquiring into the digestion of liquids, we shall follow the same order as that observed in considering the digestion of solids; but as many of the acts are accomplished in the same manner, it will not be necessary to dwell upon them.

Thirst or the desire for drink is an internal sensation; in its essence resembling that of hunger, although not referred to the same organs. It arises from the necessities of the system; from the constant drain of the fluid portions of the blood; and is instinctive or essentially allied to organization.[1] The sensation differs in different persons, and is rarely alike in the same. Usually, it consists of a feeling of dryness, constriction, and heat in the back part of the mouth, pharynx, œsophagus, and occasionally in the stomach; and, if prolonged, redness and tumefaction of the parts supervene, with a clammy condition of the mucous follicular—and diminution and viscidity of the salivary—secretions. These phenomena are described as being accompanied by restlessness, general heat, injected eyes, disturbed mind, acceleration of the circulation, and short breathing, the mouth being frequently and largely open, so as to admit the air to come in contact with the irritated parts, and thus afford momentary relief.

Thirst is a very common symptom of febrile and inflammatory diseases, in which fluid—especially cold fluid—is desired in consequence of the local relief it affords to the parched and heated membrane of the alimentary canal. It is also developed by extraneous circumstances, as in summer, when the body sustains considerable loss of fluid; as well as in those diseases—dropsy, diabetes, &c.—which produce the same effect. There are many other circumstances, however, that excite it;—long speaking or singing; certain kinds of diet as the saline and spicy,—and especially the habit, acquired by some, of drinking frequently. Whilst individuals, thus circumstanced, may need several gallons a day to satisfy their wants;—others, who have, by resistance, acquired the habit of using very little liquid, may be enjoying health, and not experiencing the slightest inconvenience from the privation of liquid; so completely are we, as regards the character and quantity of our aliment, the creatures of habit. This privation, it is obvious, cannot be absolute or pushed beyond a certain extent. There must always be fluid enough taken to administer to the necessities of the system.

As in the production of all sensations, three acts are required for accomplishing that of thirst;—impression, conduction, and perception. The last, as in every similar case, is effected by the brain; and the second by the nerves passing between the part impressed and that organ. The act of impression—its seat and cause—will alone arrest our attention, and it will be found that we are still less instructed on these points than on the physiology of hunger. Even with regard to the seat of the impression, we are in a state of uncertainty. It appears to be chiefly in the back part of the mouth and fauces; but whether

[1] J. Béclard, Traité Élémentaire de Physiologie, p. 28, Paris, 1855.

primarily there, or experienced there by sympathy with the condition of the stomach, is by no means clear. The latter opinion, however, appears the more probable. In a remarkable case, published by Dr. Gairdner of Edinburgh, it was found impracticable to allay thirst by merely supplying the mouth, tongue, and fauces with fluid. A man had cut through the œsophagus. An insatiable thirst arose; several pailfuls of water were swallowed daily, and discharged through the wound without removing the desire for drink; but on injecting water, mixed with a little spirit, into the stomach, it was soon quenched. That the sensation is greatly dependent upon the quantity of fluid circulating in the vessels is shown by the fact, mentioned by M. Dupuytren, that he succeeded in allaying the thirst of animals, by injecting milk, whey, water or other fluids into the veins; and M. Orfila states, that, in his toxicological experiments, he frequently allayed in this way the excessive thirst of animals, to which he had administered poison; and which were incapable of drinking, owing to the œsophagus having been tied. He found, also, in his experiments, that the blood of animals was more and more deprived of its watery portions as the abstinence from liquids was more prolonged.[1]

Like all other sensations, that of thirst arises from an inappreciable modification of the nerves of the organ: hence, all the hypotheses proposed to account for it have been mere fantasies undeserving of enumeration.

The *prehension of liquids* differs somewhat from that of solids. The fluid may be simply poured into the mouth, or a vacuum may be formed in it: the pressure of the atmosphere then forces it in. When we *drink* from a vessel, the mouth is applied to the surface of the fluid; the chest is then dilated, so as to diminish the pressure of the atmosphere on the portion of the surface of the liquid intercepted by the lips; and the atmospheric pressure on the surface of the fluid in the vessel forces it into the mouth, to replace the air that has been drawn from the mouth by the dilatation of the thorax. In *sucking*, the mouth may be compared to an ordinary syringe; the nozzle of which is represented by the lips; the body by the cheeks, palate, &c., and the piston by the tongue. To put this in action, the lips are accurately adjusted around the body from which the liquid has to be extracted. The tongue is likewise applied, contracts, and is carried backwards; so that an approach to a vacuum is formed between its upper surface and the palate. The fluid, no longer compressed equally by the atmosphere, is displaced, and enters the mouth.

As neither mastication nor insalivation is required in the case of liquids, they do not remain long in the mouth, unless their temperature is too elevated to admit of their being passed down into the stomach immediately, or they are of so luscious a character, that their prolonged application to the organ of taste affords pleasure. Their deglutition is effected by the same mechanism as that of solids; and, as they yield readily to the slightest pressure, with less difficulty. Their accumulation in the stomach takes place in much the same manner. They arrive by successive mouthfuls; and, as they collect, the thirst disappears

[1] Adelon, Physiologie de l'Homme, 2de édit., ii. 525, Paris, 1829.

with all its local and general attendants. If, however, the organ be over-distended a disposition to vomiting is induced.

The changes, which liquids undergo in the stomach, are of different kinds. All acquire the temperature of that viscus, and become mixed with the secretions from its internal surface, as well as from that of the supra-diaphragmatic portion of the digestive tube. Some, however, undergo the operation of chymification; others not. To the latter class belong,—water, weak alcoholic drinks, the vegetable acids, &c. Water experiences the admixture already mentioned; becomes turbid, and gradually disappears, without undergoing any transformation. Part passes into the small intestine; the other is directly absorbed. When any strong alcoholic liquor is taken, the effect is different. Its stimulation causes the stomach to contract, and augments the secretion from the mucous membrane; whilst, at the same time, it coagulates all the albuminous portions; mixes with the watery part of the mucous and salivary fluids, and rapidly disappears by absorption; hence, the speedy supervention of inebriety, or death, after a large quantity of alcohol has been taken into the stomach. The substances, that have been coagulated by the action of the alcohol, are afterwards digested like solid food. We can thus understand the good effects of a small quantity of alcohol, taken after a substance difficult of digestion,—a custom which has existed from high antiquity, and has physiology in its favour. It is, in such cases,—to use the language of the eccentric Kitchener,[1]—a good "*peristaltic persuader.*"

Oil remains longer in the stomach than any other liquid, experiences little change there, but passes into the small intestine, where it forms an emulsion and enters the veins and chyliferous vessels. Milk, as is well known, coagulates in the stomach soon after it is swallowed, after which the clot is digested, and the whey absorbed. Yet the existence of coagula in the stomach is constantly regarded by the unprofessional as a pathological condition! Where the liquid, aqueous or spirituous, holds in suspension the immediate principles of animals or vegetables, as gelatin, albumen, osmazome, sugar, gum, fecula, colouring matter, &c., there is reason to believe that they enter immediately into the veins of the stomach and small intestine, having become modified and rendered fit for assimilation by admixture with the gastric and intestinal secretions. The salts, united with these fluids, are taken up along with them. Red wine, according to M. Magendie,[2] first becomes turbid by admixture with the juices formed in, or carried into, the stomach; the albumen of these fluids speedily undergoes coagulation, and becomes flocculent; and, subsequently, its colouring matter—entangled, perhaps, with the mucus and albumen—is deposited on the mucous membrane of the stomach. The aqueous and alcoholic portions soon disappear.

Liquids reach the small intestine in two forms;—in the state of chyme; and in their unaltered condition. In the former case, they proceed like the chyme obtained from solid food. In the latter, they

[1] Directions for Invigorating and Prolonging Life; or the Invalid's Oracle, &c., Amer. edit., from the 6th London, by T. S. Barrett, New York, 1831.

[2] Précis, &c., ii. 143.

undergo no essential change; being simply united with the fluids poured into the small intestine,—the mucous secretions, bile and pancreatic juice. Their absorption goes on as they proceed, so that very little, if any, attains the large intestine. The mode in which they are expelled is the same as in the case of solids.

6. ERUCTATION, REGURGITATION, RUMINATION, AND VOMITING.

Although the contraction of the œsophagus generally prevents the return of matters from the stomach, occasionally this occurs, giving rise to *eructation*, *regurgitation*, or *vomiting*.

a. *Eructation.*—Eructation or belching is the escape of gas from the stomach. If air exists in the organ, it is necessarily situate near the cardiac orifice. When the aperture relaxes, it passes out, and, unless forced back by the contraction of the œsophagus, speedily reaches the pharynx, causing the edges to vibrate, hence the sound by which it is accompanied.

b. *Regurgitation.*—If, instead of air, liquid or solid food ascends from the stomach into the mouth, the action is called *regurgitation.* Of this we have an instance in the puking of the infant at the breast; and in the adult, when the stomach is surcharged. Occasionally, too, it occurs when the organ is empty,—in the morning, for example,—when it is frequently preceded by eructations, by which the air, contained in the organ, is got rid of. The mode in which it takes place is analogous to that of eructation. The substances, contained in the stomach become accidentally engaged in the cardiac orifice, during the open state of the orifice, and the relaxation of the lower part of the œsophagus, owing to the direct pressure of the stomach on its contents, and the abdominal muscles contracting and compressing that viscus. When they have once passed into the œsophagus, the latter contracts upon them but inversely, or from below to above. In this way they ascend into the pharynx, and ultimately into the mouth. Generally, regurgitation takes place in an involuntary manner; but there are some who are capable of effecting it at will; and can discharge the contents of their stomachs at pleasure. To accomplish this,—a deep inspiration is taken, by which the diaphragm is forcibly depressed upon the stomach; the abdominal muscles are then contracted so as to compress the organ; and this effect is occasionally aided by pressing strongly with the hands on the epigastric region. When these efforts are simultaneous with the relaxation of the lower third of the œsophagus, the alimentary matters pass into the œsophagus. This voluntary regurgitation seems to be what is called *vomiting at pleasure.*

Professor Bérard[1] has remarked, that when food passes from the mouth into the pharynx, in the act of deglutition, the reflex action of the second stage precipitates it into the œsophagus without any act of the will; but when food ascends from the œsophagus into the pharynx, it can be introduced at will into the mouth, or be swallowed.

c. *Rumination.*—Some individuals have taken advantage of this power to chew the food over again, and subject it to a second deglutition. The function of *rumination* is peculiar to certain animals; yet

[1] Cours de Physiologie, ii. 275 (note), Paris, 1849.

man has occasionally possessed it. Peyer,[1] as well as Percy and Laurent,[2] has given numerous examples. The wife of a *frotteur* or rubber of the floors, in the establishment of the then Duke of Orleans—afterwards King Louis Philippe—could bring up a glassful of water into her mouth immediately after she had swallowed it. Dr. Copland[3] appears to have seen more than one instance of human rumination, and he describes it as an affection rather to be courted than shunned, so far as regards the sensations of the individual.[4] Under usual circumstances, according to him, rumination commences from a quarter of an hour to an hour and a half after a meal. The process is never accompanied with the smallest degree of nausea, pain, or disagreeable sensation. The returned alimentary bolus is attended with no unpleasant flavour; is in no degree acidulous [?]; is agreeable; and masticated with additional pleasure, and greater deliberation than at first. The whole of the food swallowed at a meal is not returned in order to undergo the process; but chiefly the part that has been insufficiently masticated. The more fluid portions are sometimes, however, regurgitated along with the more solid; and when the stomach is distended by a copious meal the fluid contents are frequently passed up to be again swallowed.[5]

d. *Vomiting.*—This inverted action of the stomach, preceded—as it always is—by manifest local and general disturbance, cannot properly be regarded as within the domain of physiology. In the language of Haller, *vomitus totus morbosus est.* It is, however, so nearly allied to the phenomena we have just considered, and has engaged so much of the time of the physiologist, as well as pathologist, that it requires mention here. From regurgitation it differs essentially,—in the sensation that precedes; the retching that accompanies; and the fatigue that generally succeeds it; in short, whilst in regurgitation no indisposition may be felt, in vomiting it is always present to a greater or less extent.

The *sensation of the desire to vomit* is termed *nausea.* It is an indescribable feeling of general indisposition; sometimes accompanied with one of circumgyration, either in the head or epigastric region; trembling of the lower lip, and copious flow of saliva. Along with these signs, there is manifest diminution of the powers of the vascular and nervous systems; hence the utility of nauseating remedies when these systems are inordinately excited. The causes, which produce nausea, show that it may be either an external or internal sensation. Those, that occasion it directly or externally, are emetics; too great distension of the stomach, or the presence of food that disagrees by its quality; morbid secretions; reflux of bile from the duodenum, &c. All these are so many immediate irritants, which develope the sensation,

[1] Merycologia, &c., Basil, 1685.

[2] Art. Mérycisme, in Dict. des Sciences Médicales; and Bérard, Cours de Physiologie, 13te livraison, p. 274, Paris, 1849.

[3] Edition of De Lys's translation of Richerand's Physiology.

[4] See also Béraud, Manuel de Physiologie, p. 152, Paris, 1853.

[5] An interesting case of rumination is cited from the London Lancet, in the Philadelphia Med. Examiner, p. 315, for May, 1845. On the sensible phenomena of rumination, see Colin, Comptes Rendus, xxxv., 130, 1852; and Scherer, Canstatt's Jahresbericht, 1852, S. 133.

as external sensations in general are developed. In other cases, the cause acts at a distance. Between the stomach and various organs of the body, such extensive sympathetic relations exist, that if one be long and painfully affected, the stomach sooner or later sympathizes; and nausea, or vomiting, or both are induced. In many instances, indeed, the cause is much more remote than this; the sight of a disgusting object, an offensive smell, or a nauseous taste, will as certainly produce the sensation as any of the more direct agents. To this class of causes belongs the nausea produced by riding in a carriage with the back to the horses, by swinging, and particularly by sailing on the ocean. How the motion, which obviously excites the nausea in these cases, acts, has been the subject of many speculations, especially as regards sea-sickness. Darwin[1] refers it to an association with some affection of the organs of vision, which, in the first instance, produces vertigo; and M. Bourru, in his French translation of the work of Gilchrist, "On the utility of sea voyages in the cure of different diseases,"—ascribes it to irritation of the optic nerves, caused by the impossibility of fixing the eyes on objects soon after embarking. The objections to these views are, that it ought to be prevented by simply covering the eyes, and that the blind ought to be exempt from it, which is not the case. Dr. Wollaston[2] attempted to explain it, by some change in the distribution of the blood;—the descending motion of the vessel causing an accumulation in the brain, as it causes the mercury to rise in the tube of a barometer. But the explanation is too physical. The mercury, in an unyielding tube, is readily influenced by the motions of the vessel; but the blood in the living animal is circumstanced far otherwise. It is under the influence of a vital force, which interferes greatly with the action of purely physical causes. Were it otherwise, we should be liable to alarming accidents, whenever the body is exposed to the slightest concussion.

The generality of pathologists consider, that the first effect is upon the brain, the sensation being produced consecutively through the influence of that organ on the stomach; and it is difficult not to accord with this view; whilst it must be admitted, that the precise mode, in which it is effected—as in the case, indeed, of every other phenomenon of the nervous system, is beyond our cognizance. In nausea, produced by the sight of a disgusting object, we have this catenation of actions somewhat more clearly evidenced. The impression is manifestly conveyed to the brain by the optic nerves, and from that organ the sensation must emanate. It is probable, too, that when emetics are injected into the veins, the first effect takes place on the brain, and the stomach is affected secondarily.

When the state of nausea, howsoever induced, continues for any length of time, it is usually followed by vomiting. The rejected matters are generally from the stomach; but if the retching or violent contractile efforts of the muscles concerned be long continued, the contents of the small intestine also form part; hence, we account for the universality of the presence of bile in the rejected matters after an emetic has been taken. Its presence is, therefore, in the generality of

[1] Zoonomia. iv. 252, 3d edit., Lond., 1801. [2] Philos. Transact. for 1810.

cases, no evidence of the person's being what is termed *bilious*. The contents of the small intestine are returned into the stomach by the antiperistaltic action. The longitudinal fibres take their fixed point below, and contract from above downwards; so that the chymous mass is forced towards the upper part of the canal, whilst the circular fibres contract from below to above. In cases of *colica ileus* or *iliac passion*, the inverted action extends through the whole intestinal canal; so that fecal matters, and even substances injected into the rectum, pass the ileo-cæcal valve, and are discharged by the mouth.

Of old, it was universally maintained, that vomiting is caused by the sudden and convulsive inverted contraction of the stomach; and they, who admitted that the diaphragm and abdominal muscles take part in the action, looked upon them simply as accessories. Francis Bayle,[1] Professor in the University of Toulouse, in 1681, appears to have been the first who suggested, that the stomach is nearly passive in the act; and that vomiting is caused almost exclusively by the pressure exerted upon that organ by the diaphragm and abdominal muscles. His reason for the belief was founded on the fact, that having introduced his finger into the abdomen of a living animal whilst it was vomiting, he could not perceive any contraction of the stomach. In 1686, M. Chirac repeated the experiment with similar results; after which, the views of Bayle were embraced by many of the most eminent physiologists and pathologists,—Sénac, Van Swieten, and Schwartz,[2] and, at a later period, by the celebrated John Hunter,[3] who maintained, that the contraction of the muscular fibres of the stomach is not essential to the act. Many distinguished physiologists ranged themselves on the opposite side. M. Littre maintained, that the stomach is provided with considerable muscular bands, capable of powerful contraction; and that vomiting, as in the case of ruminant animals, is often caused without the participation of the abdominal muscles. We have seen, however, that the rumination of animals more resembles regurgitation. M. Lieutaud[4] argued, that, according to Bayle's theory, vomiting ought to be a voluntary phenomenon; that the stomach is too deeply seated to be compressed, so as to empty it of its contents, by the neighbouring muscles; and he details the singular case of a female, who, whilst labouring under an affection, for which emetics seemed to be required, resisted the action of the most powerful substances of that nature. After her death, M. Lieutaud, feeling desirous to detect the cause of this resistance, had the body opened in his presence; the stomach was found enormously distended, but its structure unaffected. He, consequently, inferred, that the stomach had become paralyzed from over-distension, and that the effect produced was similar to that, so often met with in the bladder, when it has been long and largely distended. This case seemed to prove to him, that the stomach is most concerned in the act of vomiting, as the abdominal muscles and diaphragm appeared healthy, and no obstacle existed to their contraction. It is singular, however, that emetics

[1] Problemata Medico-physica et Medica, Hagæ Comitis, 1678.

[2] Haller, Elementa Physiol., lib. xix. § 4, Bern., 1764.

[3] Observations on certain parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 121, Philad., 1840.

[4] Mémoir. de l'Acad. pour 1752, p. 223.

should not have excited the contraction of the diaphragm and abdominal muscles; especially as there is reason for believing, that many of them at least, under ordinary circumstances, are taken into the bloodvessels, and affect the brain first, and through its agency the muscles concerned in the act of vomiting. The case seems to have been one of unusual resistance to the ordinary effects of nauseating substances, and cannot be looked upon as either favourable or unfavourable to the views of Bayle. We find, that vomiting does not follow the exhibition of the largest doses of the most powerful emetics, if the energy of the nervous system be suspended by the inordinate use of narcotics, or by violent injuries of the head. M. Lieutaud farther remarks, that according to Bayle's theory vomiting occurs at the time of inspiration; but this cannot be, as the lower part of the œsophagus is then contracted, and if the vomited matters could reach the pharynx, they would pass into the larynx.

Dr. Marshall Hall[1] has attempted, and successfully, to show, that the larynx is closed during vomiting; and has concluded, that the act is a modification of expiration,—or that the muscles of expiration, by a sudden and violent contraction, press upon the contents of the stomach, and project them through the œsophagus. Perhaps—as Dr. Hall has remarked—no act affords a better illustration of the action of the excito-motory or reflex system of nerves than this. If the upper part of the throat be tickled with a feather, vomiting results; but if the feather be passed too far down, deglutition is induced and not vomiting. The excitor nerves, in the former case, are the glosso-pharyngeal, and perhaps the fifth pair. When vomiting is caused by an emetic, the pneumogastric is the excitor. When the impression is first made on the brain, the stimulus must be conveyed by the medulla oblongata and medulla spinalis to the muscles concerned.

Haller[2] maintained the ancient doctrine, that the stomach, alone, is competent to the operation. His views were chiefly founded on his theory of irritability, which compelled him to admit contraction wherever there are muscular fibres; and on certain experiments of Wepfer,[3] who asserted, that when he produced vomiting by mineral substances, he observed the stomach contract. The *Académie des Sciences* of Paris, unsatisfied with the results of previous observations, appointed M. Duverney[4] to examine into the question, experimentally and otherwise; who—although he did not adopt the whole theory of Chirac—confirmed the accuracy of the facts on which it rested. He demonstrated, that the stomach is but little concerned in the act; and that it is chiefly dependent upon the contraction of the diaphragm and abdominal muscles, which enclose the stomach as in a press, so that its contents are compelled to return by the œsophagus. On the other hand, in 1771, M. Portal,[5] in his lectures at the College of France, endeavoured to show, that the stomach is the great agent. He administered to two dogs arsenic and nux vomica, which produced vomiting. The abdomen was immediately opened; and, according to Portal, the contractile move-

[1] Journal of Science and Arts, xv. 388.
[2] Loc. citat.
[3] Cicutæ Aquaticæ Historia, &c., Basil, 1679.
[4] Mémoir de l'Academ. pour 1700, Hist., p. 27.
[5] Cours d'Anatomie Médicale, Paris, 1804.

ments of the stomach could be both seen and felt; and it was noticed, that instead of the vomiting being dependent upon the pressure of the diaphragm on the stomach, it occurred at the time of expiration; and was arrested during inspiration, because the depressed diaphragm then closes the inferior extremity of the œsophagus with such strength, that the contents cannot be forced into the œsophagus when we press upon the organ with both hands. The views of Portal were confirmed by the experiments of Dr. Haighton.[1] He opened several animals during the efforts of vomiting; and states that he distinctly saw the contractions of the stomach.

In more recent times, the physiological world has been again agitated with this question. In 1813, M. Magendie[2] presented to the French Institute the results of a series of experiments on dogs and cats,—animals, that vomit with facility. Six grains of tartrate of antimony and potassa were given to a dog, and, when he became affected with nausea, the linea alba was divided, and the finger introduced into the abdomen to detect the state of the stomach. No contraction was felt; the organ appeared simply pressed upon by the liver and intestines crowded upon it by the contracted diaphragm and abdominal muscles. Nor was any contraction of the stomach perceptible to the eye; on the contrary, it appeared full of air, and three times its usual size. The air manifestly came from the œsophagus, as a ligature, applied round the cardia, completely shut it off. From this experiment, M. Magendie inferred, that the stomach is passive in vomiting. A solution of four grains of tartrate of antimony and potassa in two ounces of water was injected into the veins of a dog; and, as soon as nausea took place, an incision was made into the abdomen, and the stomach drawn out of the cavity. Although the retching continued, the viscus remained immovable; and the efforts were vain. If, on the other hand, the anterior and posterior surfaces of the stomach were pressed upon by the hands, vomiting occurred, even when no tartrate was administered,—the pressure provoking the contraction of the diaphragm and abdominal muscles, and thus exhibiting the close sympathetic connexion, existing between those acts. A slight pull at the œsophagus was attended with a similar result. In another dog, the abdomen was opened; the vessels of the stomach tied; and the viscus extirpated. A solution of two grains of tartrate of antimony and potassa in an ounce and a half of water was then injected into the veins of the animal, when nausea and fruitless efforts to vomit supervened. The injection was repeated six times: and always with the same results.—In another dog, the stomach was extirpated, and a hog's bladder fitted to the œsophagus in its stead, containing a pint of water, which distended but did not fill it. The whole was then put into the abdomen; the parietes of which were closed by suture. A solution of tartrate of antimony and potassa was now injected into the jugular vein: nausea—and, afterwards, vomiting—supervened, and the fluid was forced from the bladder.—In another dog, the phrenic nerves were divided; by which three-fourths of the diaphragm were paralysed; the dorsal being the only nerves of

[1] Memoirs of the Lond. Med. Society, vol. ii.

[2] Mémoire sur le Vomissement, Paris, 1813; and Précis Élémentaire, edit. cit., ii. 152.

motion remaining untouched. When tartrate of antimony and potassa was injected into the veins of this animal, but slight vomiting occurred; and this ceased, when the abdomen was opened, and the stomach forcibly pressed upon.—In another dog, the abdominal muscles were detached from the sides and linea alba;—the only part of the parietes remaining being the peritoneum. A solution of tartrate of antimony and potassa was now injected into the veins: nausea and vomiting supervened; and, through the peritoneum, the stomach was observed immovable; whilst the diaphragm pressed down the viscera so strongly against the peritoneum, that it gave way, and the linea alba alone resisted.—In a final experiment, he combined the last two. He cut the phrenic nerves to paralyse the diaphragm; and removed the abdominal muscles. Vomiting was no longer excited.

From these different results, M. Magendie decided, that vomiting takes place independently of the stomach; and, on the other hand, that it cannot occur without the agency of the diaphragm and abdominal muscles; and he concluded, that the stomach is almost passive in the act;—that the diaphragm and abdominal muscles, especially the first, are the principal agents;—that air is constantly swallowed at the time of vomiting, to give the stomach the bulk which is necessary, in order that it may be compressed by those muscles; and lastly, that the diaphragm and abdominal muscles are largely concerned in vomiting, as is indicated by their evident and powerful contractions, and by the fatigue felt in them afterwards. In corroboration of his view, M. Magendie refers to cases of scirrhous pylorus, in which there is constant vomiting, although a part of the tissue of the stomach has become of cartilaginous hardness, and, consequently, incapable of contraction.

Clear as the results obtained by this practiced experimenter seem to be, they have been controverted; and attempted to be overthrown by similar experiments. Soon after the appearance of his memoir, M. Maingault[1] laid before the Society of the *Faculté de Médecine* of Paris, a series of experiments, from which he deduced very different results. In all, vomiting was produced without the aid of the diaphragm and abdominal muscles. The vomiting was excited by pinching a portion of intestine, which acts more speedily than the injection of substances into the veins. The abdomen of a dog was opened, and a ligature passed round a portion of intestine, which was returned into the abdomen, and the wound closed by suture: vomiting took place. All the abdominal muscles were next extirpated,—the skin, alone, forming the parietes of the cavity. This was brought together, and the vomiting continued. On another dog, three-quarters of the diaphragm were paralysed by the section of the phrenic nerves. The abdomen was now opened, and a ligature placed round a portion of intestine. Vomiting occurred. Lastly;—these two experiments were united into one. The abdominal muscles were cut crucially, and removed; the phrenic nerves divided; and the diaphragm was cut away from its fleshy portion towards its tendinous centre; leaving only a portion as broad as the finger under the sternum. The integuments were not brought together; yet vomiting continued.

[1] Mémoire sur le Vomissement, Paris, 1813.

As these results were obtained on numerous repetitions of the experiment, M. Maingault conceived himself justified in deducing inferences opposite to those of M. Magendie, namely,—that the contraction of the diaphragm and abdominal muscles is only accessory to the act of vomiting; that the action of the stomach is its principal cause;—that the latter is not a convulsive contraction, which strikes the eye, but a slow, antiperistaltic action; and that the only convulsive movement is the contraction of the œsophagus, which drags the stomach upwards. He adduces, moreover, various considerations in favour of his deductions. If the stomach, he asks, be passive, why does it possess nerves, vessels, and muscular fibres? Why is vomiting more energetic, when the stomach is pinched nearer to its pyloric orifice? Why are the rugæ of the mucous membrane of the stomach, during vomiting, directed in a divergent manner from the cardiac and pyloric orifices towards the middle portion of the organ? If the diaphragm does all, why do we not vomit whenever that muscle contracts forcibly? Why does not the diaphragm produce the discharge of urine in paralysis of the bladder? Why is vomiting not a voluntary phenomenon? And, lastly, how is it that it occurs in birds, which have no diaphragm?

The minds of physiologists were of course distracted by these conflicting results. M. Richerand[1] embraced the views of M. Magendie; and affirmed, that he had never observed contraction of the stomach; and that it seemed to him the least contractile of any part of the intestinal canal. With regard to the experiments of M. Maingault, he considered, that the stomach had not been wholly separated from the surrounding muscles; that the action of the pillars of the diaphragm, and the spasmodic constriction of the hypochondres are sufficient to compress the viscus; that nothing is more difficult to effect than the section of the phrenic nerves below their last root; and, moreover, such section does not entirely paralyse the diaphragm, as the muscle still receives twigs from the intercostal nerves and great sympathetic; that the cardia, being more expanded than the pylorus, the passage of substances through it is rendered easy; and that it is incorrect to say, that the cardiac orifice, during inspiration, is closed between the pillars of the diaphragm. Again, to object that, according to the theory of M. Magendie, vomiting ought to be a voluntary phenomenon, is a feeble argument; for it is admitted, that the muscles, which, at the time, compress the stomach, act convulsively. If the diaphragm, in paralysis of the bladder, cannot effect the excretion of the urine, it is because that reservoir is not favourably situate as regards the muscle; and, lastly, the arguments deduced from birds, that they are capable of vomiting, although they have no diaphragm, is equally insufficient, for it is not absolutely necessary that it should be a diaphragm, but any muscle that can compress the stomach.

When the Memoir of M. Maingault was presented to the society of the *Faculté de Médecine*, M. Legallois and Professor Béclard were named reporters. The experiments were repeated before them by M. Maingault; but, instead of appearing contradictory to those of Ma-

[1] Nouveaux Élémens de Physiologie, 7ème édit., Paris, 1817.

gendie, these gentlemen declared, that they were not sufficiently multiplied, nor sufficiently various, to lead to any positive conclusion. MM. Legallois and Béclard subsequently repeated and varied them; and instituted others, from which they deduced corollaries, entirely conformable to those of M. Magendie;[1] and lastly, M. Bégin[2] boldly affirms, "without fear of being contradicted by facts, that there is no direct or authentic experiment, that demonstrates the activity of the stomach during vomiting:"—and he adds, "I have repeated the greater part of the experiments of Magendie; he has performed all in presence of a great number of spectators, of whom I was one; and I can say, with the commissioners of the *Académie des Sciences*, that I have seen, examined, touched, and my conviction is full and entire." Still, many eminent physiologists have adhered to the idea, that the stomach is the main agent in vomiting; and among these was M. Broussais.[3] He manifestly, however, confounded the phenomena of regurgitation with those of vomiting; which, we have endeavoured to show, are distinct.

A case of wound of the left hypochondrium with escape of the stomach was described to the *Académie Royale de Médecine*, by M. Lépine, and reported upon by MM. Lagneau, Gimelle, and Bérard,[4] which confirms the views adopted by M. Magendie. During the whole of the period, that the stomach remained out of the abdominal cavity, there was no apparent contraction of the muscular fibres of the organ, and none of its contents were expelled, although the patient made violent efforts to vomit. As soon, however, as the stomach had been returned into the abdomen, the efforts were followed by the expulsion of its contents. M. Lépine confirms the observations of Magendie in another point. After each act of vomiting, the patient appeared to swallow air. "I observed him," says M. Lépine, "execute repeated acts of deglutition, each of which was accompanied by a noise, that seemed to be owing to the passing back of air."[5]

On the whole, we are, perhaps, justified in concluding, that the ancient doctrine regarding vomiting is full of error, and ought to be discarded; that the inverted action of the stomach, although not energetic, is necessary,—that the pressure, exerted on the parietes of the stomach by the diaphragm and abdominal muscles, is a powerful cause, —and that the more or less complete paralysis of the diaphragm, or destruction of the abdominal muscles, renders vomiting more feeble and more slow in manifesting itself. The deep inspiration preceding the act of vomiting, is terminated by the closure of the glottis: after this the diaphragm cannot move without expanding or compressing the

[1] Bulletin de la Faculté et de la Société de Méd., 1813, No. x., and Œuvres de Legallois, Paris, 1824.

[2] Traité de Thérapeutique, Paris, 1825.

[3] Traité de Physiologie, etc., translated by Drs. Bell and La Roche, p. 345, Philad., 1832.

[4] Bulletin de l'Académie Royale de Médecine, 1844. See cases cited in Philad. Med. Examiner, April 20, 1844, p. 92; also a case of Wound of Abdomen, in Amer. Journ. of the Med. Sciences, Oct. 1846, p. 379.

[5] The case described by Lépine has, as properly remarked by Dr. Brinton, (Cyclop. of Anat. and Physiology, art. Stomach and Intestines, Pt. 46, p. 317, Lond., 1855,) "been strangely misquoted by many English authors." See Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 180, Philad., 1853; and Carpenter, Principles of Human Physiology, Amer. edit., p. 96, Philad., 1855.

air in the lungs. It, consequently, presents a resisting surface, against which the stomach may be pressed by the contracting abdominal muscles. The order of the phenomena seems to be as follows. The brain is affected directly or indirectly by the cause exciting vomiting;—through the brain and medulla, the glottis is closed, and the diaphragm and abdominal muscles are thrown into appropriate contraction, and press upon the stomach; this organ probably contracts from the pylorus towards the cardia; and, by the combination of efforts, the contents are propelled into the œsophagus, and out of the mouth. These efforts are repeated several times in succession, and then cease, —to reappear at times. Whilst the rejected matters pass through the pharynx and mouth, the glottis closes; the velum palati rises and becomes horizontal as in deglutition; but owing to the convulsive action of the parts, these apertures are less accurately closed, and more or less of the vomited matter passes into the larynx or nasal fossæ. On account of the suspension of respiration impeding the return of blood from the upper parts of the body, and partly owing to the force with which the blood is sent through the arteries, the face is flushed, or livid, the perspiration flows in abundance, and the secretion of tears is largely augmented.

CHAPTER II.

ABSORPTION.

In the consideration of the preceding functions, we have seen the alimentary matter subjected to various actions and alterations; and at length, in the small intestine, possessed of the necessary physical constitution for the chyle to be separated from it. Into the mode in which this separation,—which we shall find is not simply a secerning action, but one of vital elaboration,—is effected, we have now to inquire. It constitutes the function of *absorption*, and its object is to convey the nutritive fluid, formed from the food, into the current of the circulation. Absorption is not, however, confined to the formation of this fluid. Liquids can pass into the blood directly through the coats of the containing vessel, without having been subjected to any elaboration; and the different constituents of the organs are constantly subjected to the absorbing action of cells, by which their decomposition is effected, and their elements conveyed into the blood; whilst antagonizing cells elaborate from the blood, and deposit fresh particles in the place of those that have been removed. These various substances, —bone, muscle, hair, nail, as the case may be,—are never found, in their compound state, in the blood; and the inference, consequently, is that at the very radicles of the absorbents and exhalants, the substance on which absorption or exhalation has to be effected, is reduced to its constituents, and this by an action, to which we know nothing similar in physics or chemistry; hence, it has been inferred, that the operation is one of the acts of vitality.

All the various absorptions may be classed under two heads:—the *external* and the *internal;* the former including those that take place on extraneous matters from the surface of the body or its prolongation—the mucous membranes; and the latter, those that are effected internally, on matters proceeding from the body itself, by the removal of parts already deposited. By some physiologists, the action of the air in respiration has been referred to the former of these; and the whole function of absorption has been defined;—the aggregate of actions, by which nutritive substances—external and internal—are converted into fluids, which serve as the basis of arterial blood. The function of respiration will be investigated separately. Our attention will, at present, be directed to the other varieties; and, first of all to that which occurs in the digestive tube.

I. DIGESTIVE ABSORPTION.

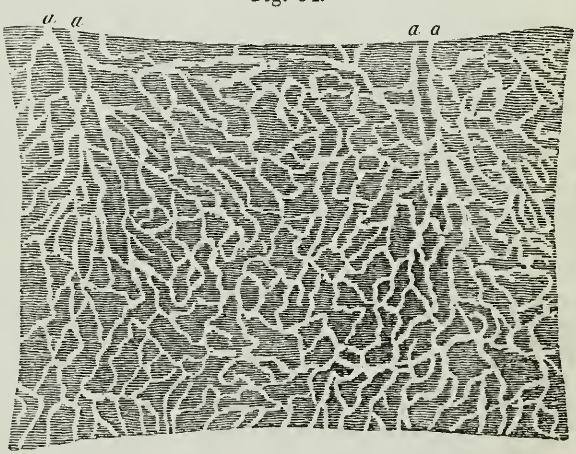
The absorption, effected in the organs of digestion, is of two kinds; according as it concerns liquids of a certain degree of tenuity, or solids. The former, it has been remarked, are subjected to no digestive action, but disappear chiefly from the stomach, and in part from the small intestine. The latter undergo conversion, before they are fitted to be taken up from the intestinal canal.

a. *Absorption of Chyle or Chylosis.*

1. ANATOMY OF THE CHYLIFEROUS APPARATUS.

In the lower animals, absorption is effected over the whole surface of the body, both as regards the materials necessary for nutrition and the supply of air. No distinct organs for the performance of these functions are perceptible. In the upper classes of animals, however, we find an apparatus, manifestly intended for the absorption of chyle, and constituting a vascular communication between the small intestine and left subclavian. Along this channel, the chyle passes, to be emptied into that venous trunk.

Fig. 54.



Chyliferous Vessels.

The *chyliferous apparatus* consists of chyliferous vessels, mesenteric glands, and thoracic duct. The *chyliferous vessels* or *lacteals* arise from the inner surface of the small intestine;—in the villi, which are at the surface of, and between, the valvulæ conniventes. Prof. E. H. Weber[1] has, however, seen them distributed

[1] Müller's Archiv., u. s. w., s. 400, Berlin, 1847.

in the interspaces between the villi; the lacteals and bloodvessels forming a close network; but he could not detect them in the parietes of the follicles of Lieberkühn. Their origin is almost imperceptible; and, accordingly, the nature of their arrangement has given occasion to much diversity of sentiment amongst anatomists. Lieberkühn[1] affirms, that, by the microscope, it may be shown that each villus terminates in an *ampullula* or oval vesicle, which has its apex perforated by lateral orifices, through which the chyle enters; and Bruch[2] affirms, that there is a cæcal ampulla or excavation in the tissue at the extremity of each villus, in which its lacteal commences; but he does not regard the ampulla as perforated.

The doctrine of open mouths of lacteals and lymphatics was embraced by Hewson,[3] Sheldon,[4] Cruikshank,[5] Hedwig,[6] and Bleuland,[7] and by some of the anatomists and physiologists of the present day;[8] but, on the other hand, it has been contested by Mascagni,[9] and others; whilst Rudolphi,[10] Meckel,[11] and numerous others[12] believed, that the lacteals have not free orifices; but that in the villi, in which absorption is effected, a spongy or sort of gelatinous tissue exists, which accomplishes absorption, and, being continuous with the mouths of chyliferous vessels, conveys the product of absorption into them, a view not unlike that of Professor Brücke to be mentioned presently. Bichat conceived them to commence by a kind of sucker or absorbing mouth, the action of which he compared to that of the puncta lachrymalia or of a leech or cupping-glass; and lastly,—from the observation, often made, that different coloured fluids, with which the lymphatics have been injected, have never spread themselves, either into the areolar tissue, or the parenchyma of the viscera,—M. Mojon,[13] of Genoa, affirmed, that lymphatics have no patulous orifice, and that they take their origin from a cellular filament, which progressively becomes a villosity, an areolar spongiole, a capillary, and, at length, a lymphatic trunk;—the absorbent action of these vessels being a kind of imbibition. Professor Müller[14] affirms, that he has never perceived any opening at the extremity of the villi: in his earlier examinations, he was unable to see appearances of foramina on any part of their surface; but he has observed, in portions of the intestines of the sheep and the ox, which had been exposed for some time to the action of water, that over the whole surface of

[1] Dissert. de Fabric. Villor. Intest. (passim.) Lugd., Bat., 1745.

[2] Siebold and Kölliker's Zeitschrift, April, 1853.

[3] Experimental Inquiries; edited by Falconer, Lond., 1774, 1777, and 1780, or Hewson's Works, Sydenham Society's edit., p. 181, Lond., 1846.

[4] The History of the Absorbent System, &c., p. 1, Lond., 1784.

[5] Anatomy of the Absorbing Vessels, 2d edit., Lond., 1790.

[6] Disquisit. Ampull. Lieberkühnii, Lips. 1797.

[7] Exper. Anatom., 1784; and Descript. Vasculor. in Intestinor. Tenuium Tunicis, Ultraj., 1797.

[8] See Henle, Allgemeine Anatomie, u. s. w. s. 569, Leipz., 1841.

[9] Vasorum Lymphaticorum Corporis Humani Historia, &c., Senis, 1787; and Prodromo d'un Opera sul Sistemo de Vase Linfatice, Siena, 1784.

[10] Anatomisch. Physiologisch. Abhandlung., Berlin, 1802.

[11] Handbuch, u. s. w. translated by Jourdan and Breschet, p. 179, Paris, 1805.

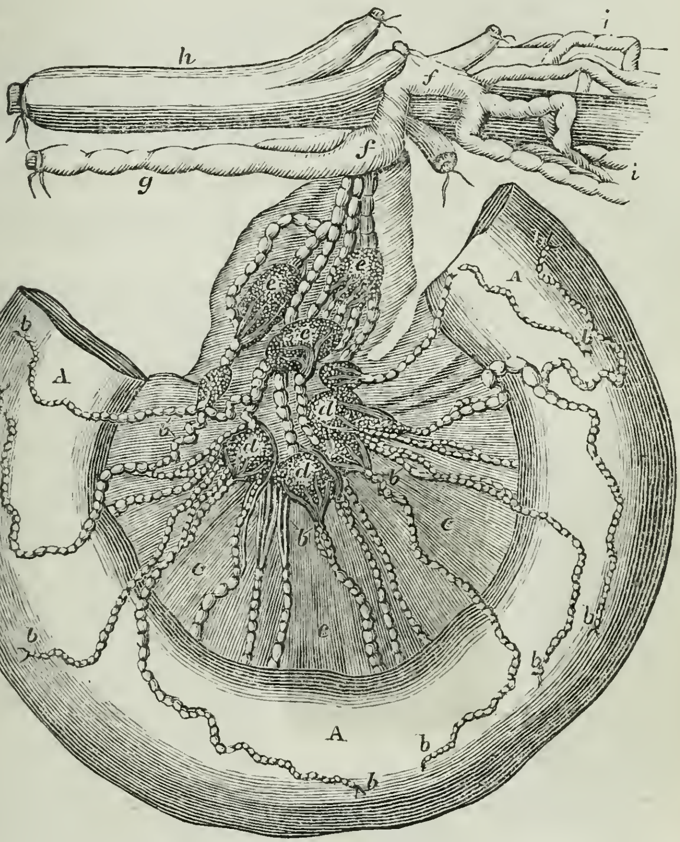
[12] F. Arnold, Lehrbuch der Physiologie des Menschen, Zürich, 1836–7; noticed in Brit. and For. Med. Rev., Oct., 1839, p. 479.

[13] Journal de la Société des Sciences Physiques, &c., Nov., 1833.

[14] Handbuch der Physiologie, u. s. w., and Baly's translation, p. 269, Lond., 1838.

the villi indistinct depressions were scattered, which might be regarded as oblique openings. He adds, however, that he makes this observation with great hesitation and distrust.

Fig. 55.



Chyliferous Apparatus.

A, A. A portion of the jejunum. *b, b, b, b.* Superficial lacteals. *c, c, c.* Mesentery. *d, d, d.* First row of mesenteric glands. *e, e, e.* Second row. *f, f.* Receptaculum chyli. *g.* Thoracic duct. *h.* Aorta. *i, i.* Lymphatics.

In conversation with the author, in July, 1854, he expressed the same views in regard to the closed condition of the villi, and his consequent dissent to those promulged by Professor Brücke,[1] of Vienna, who affirms, that the epithelial cells covering the villi are open towards the intestine; the apertures being covered with a mucous (*schleimig*) substance; and at the opposite surface they open into the lacteals, which he regards, at their commencement, as mere cavities in the centre of the villus without any distinct walls, the true lacteals originating from these spaces in the substance of the villi. Prof. Brücke's views are also con-

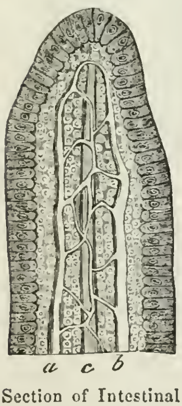
[1] Ueber die Chylusgefässe und die Resorption des Chylus, Wien, 1853.

tested by Kölliker, Bruch, Henle,[1] and others; and if we admit, with him, that such an arrangement might enable us to explain more readily how fatty and insoluble substances pass into the circulation; the difficulty which applies to every doctrine of the open mouths of the chyliferous vessels, as to the mode in which chylosis is accomplished, would still remain. As hereafter remarked, instead of any act of elaboration being executed, the chyle would necessarily have to be formed in the alimentary canal. Professor Brücke, it is true, states, that as the chyle in the villi surrounds the bloodvessels, an interchange of some of the elements takes place; the blood gives fibrin to the chyle; and the chyle a portion of its soluble materials to the blood.[2]

It has been elsewhere remarked (page 85), that numerous muscular fibre-cells have been observed in the villi,—an arrangement which accounts anatomically for the movement observed in them by different histologists.

The marginal illustration, Fig. 57, from Krause, exhibits the appearance presented by the incipient chyliferous vessels in the villi of the jejunum of a young man, who had been hanged soon after taking a full meal of farinaceous food. The chyliferous vessel issuing from each villus appeared to arise by several small branches, in some of which free extremities could be traced, whilst others anastomosed with each other. The arrangement of the different anatomical constituents is well seen in Fig. 56, which represents an injected intestinal villus of a cat, which was killed during digestion. When they become perceptible to the eye, they are observed as in Fig. 54, communicating frequently with each other; and forming a minute network, first between the muscular and mucous membranes, and afterwards between the muscular and peritoneal, until they terminate in larger trunks, *a*, *a*, *a*, *a*. When they attain the point at which the peritoneal coat quits the intestine, they also leave it; creep for an inch or two in the substance of the mesentery; and enter a first row of mesenteric glands. From these they issue, of a greater size and in less number; proceed still farther along the mesentery, and reach a second row, into which they enter. From these, again, they issue, larger and less numerous; anastomosing with each other; and proceeding towards the lumbar portion of the spine, where they terminate in a common reservoir,—

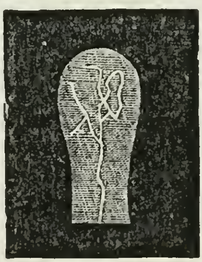
Fig. 56.



Section of Intestinal Villus.

a. Artery. *b*. Vein. *c*. Lymphatic. — Magnified 250 diameters.

Fig. 57.



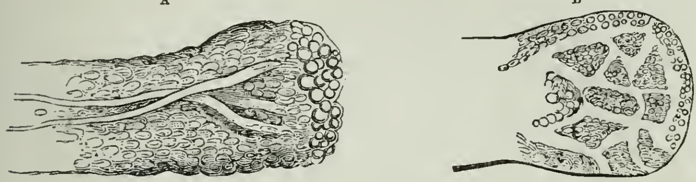
Intestinal Villus with the commencement of a Lacteal.

[1] Canstatt's Jahresbericht, 1853, 1ster Band. s. 24, Würzburg, 1854.

[2] For an abstract of Prof. Brücke's views, see a note by Dr. Da Costa, in his Amer. edit. of Kölliker's Manual of Human Histology, p. 516, Philad., 1854.

the *reservoir* of Pecquet, *receptaculum* seu *cisterna chyli* (Figs. 55 and 60)—which is the commencement of the thoracic duct. This reservoir

Fig. 58.

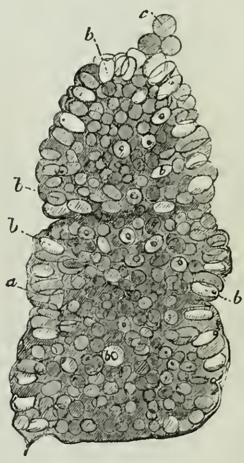


Extremity of Intestinal Villus.

A. During absorption, showing absorbent cells and lacteal trunks, distended with chyle. B. During interval of digestion, showing the supposed peripheral network of lacteals.

is situate about the third lumbar vertebra; behind the right pillar of the diaphragm, and the right renal vessels. The chyliferous vessels generally follow the course of the arteries; but sometimes proceed in the spaces between them. They exist in the lower part of the duodenum, throughout the whole of the jejunum, and in the upper part of the ileum. M. Voisin[1] affirms, that all, or at least the major part, of them pass through the substance of the liver, before they empty their contents into the thoracic duct. After proceeding a certain distance, they anastomose, he says, with each other, enlarge in size, and are collected together so as to form a kind of plexus below the lobe of Spigelius, towards which they converge. From this point, they penetrate the substance of the liver, through which they ramify with great minuteness, and finally empty themselves into the receptaculum chyli. To prove, that the chyliferous vessels do pass through the liver, he put a ligature around the duct below the diaphragm, in a dog which had eaten largely, and when digestion was in full activity. The chyliferous vessels were observed to swell, and their whitish colour was distinctly perceived. They could be traced, without much difficulty, from the interior of the intestinal canal, through the mesenteric glands, as far as their entrance into the liver.

Fig. 59.



Extremity of an Intestinal Villus during absorption.

a. Marginal layer of epithelium-cells. *b.* Epithelium-cells turgid with oleaginous matter. *c.* Adherent oil-globules.

The chyliferous vessels are composed of two coats; the outer of a fibrous and firm character, into whose composition muscular fibre-cells have been found, by Kölliker, to enter largely; the inner very thin, epithelial, and generally considered to form, by its duplicatures, *valves.* These are of a semilunar form, arranged in pairs, and with the convex side towards the intestine. Their arrangement has appeared to be well adapted for permitting the chyle to flow from the intestine to the tho-

[1] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.

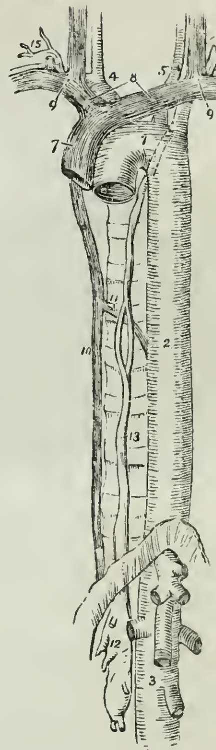
racic duct, and for preventing its retrograde course; but M. Magendie[1] affirms, that their existence is by no means constant. These reputed valves are considered by M. Mojon[2] to be true sphincters. By placing the lymphatic vessels on a glass plate, and opening them through their entire length, he observed by the microscope, that they are formed of circular fibres, which, by diminishing the size of the vessel at different points, give rise to the nodosities observed externally. If the ends of a varicose lymphatic be drawn in a contrary direction, these nodosities disappear, as well as the supposititious valves. Mojon observed, moreover, that the fibrous membrane of the lymphatics has longitudinal, as well as oblique, filaments passing from one narrow portion to another. The longitudinal fibres have their two extremities attached to the transverse fibres, which, according to him, constitute the sphincters or contractors of the lymphatics. He explains the difficulty often experienced in attempting to inject the lymphatic vessels in a direction contrary to the course of the lymph, by the circumstance, that the little pouches formed by the sphincters, and the relaxation or distension of their parietes on filling them with injected matter, diminish the calibre of the tube, and can even close it entirely. The smallest lacteals appear to be destitute of valves; but valves are perceptible in those of less than one-third of a line in diameter, and they have the same structure as those of the veins. The minute lacteals in the villi are said to consist of a single membrane with elongated cell-nuclei, corresponding to the longitudinal fibrous membrane of the veins, but not lined by epithelium. Some anatomists describe an external coat, formed of condensed areolar tissue, which unites the chyliferous vessels to the neighbouring parts.

The *mesenteric glands* or *ganglions* are small, irregularly lenticular organs; varying in size from the sixth of an inch to an inch; nearly one hundred in number, and situate between the two laminæ of the mesentery. In them, the lymphatic vessels of the abdomen terminate; and the chyliferous vessels traverse them in their course from the intestine to the thoracic duct. Their substance is of a pale rosy colour; and their consistence moderate. By pressure, a transparent and inodorous fluid can be forced from them; which has never been examined chemically. Anatomists differ with regard to their structure. According to some, they consist of a pellet of chyliferous vessels, folded a thousand times upon each other; subdividing and anastomosing almost *ad infinitum;* united by areolar tissue, and receiving a number of bloodvessels. In the opinion of others, again, cells exist in their interior, into which the *afferent* chyliferous vessels open; and whence the *efferent* set out. These are filled with a milky fluid, carried thither by the lacteals or exhaled by the bloodvessels. Notwithstanding the labours of Nuck,[3] Hewson, Abernethy, Mascagni, Cruikshank, Haller,[4] Béclard,[5] and other distinguished anatomists, the texture of these, as well as of the lymphatic glands or ganglions in general, is not demonstrated. The

[1] Précis Élémentaire, 2de édit., ii. 177, Paris, 1825.
[2] Op. citat. and Amer. Journal, &c., for Aug. 1834, p. 465.
[3] Adenologia, Lugd. Bat., 1696.
[4] Element. Physiol., lib. ii. § 3, Lausan., 1757.
[5] Addit. à Bichat, p. 128, Paris, 1821.

chyliferous and sanguiferous vessels become extremely minute in their substance; and the communication between the afferent and efferent vessels is very easy; as mercurial injections pass readily from the one to the other. According to Mr. Goodsir, the absorbent vessels within the chyliferous and lymphatic glands lay aside all but their internal coat; and the epithelium, instead of forming a thin lining of flat transparent scales, as in the extra-glandular lymphatics, acquires an opaque granular aspect, and is converted into a thick irregular layer of spherical nucleated corpuscles, measuring on an average $\frac{1}{5000}$th part of an inch in diameter, so as to suggest the idea of lymph or chyle corpuscles generated on the internal membrane after the ordinary manner of epithelium cells, and about to be thrown off into the vessel. This layer, according to Mr. Goodsir, is thickest in those lymphatics that are situated towards the centre of

Fig. 60.



Thoracic Duct.

1. Arch of aorta. 2. Thoracic aorta. 3. Abdominal aorta, showing its principal branches divided near their origin. 4. Arteria innominata, divided into right carotid and right subclavian arteries. 5. Left carotid. 6. Left subclavian. 7. Superior cava, formed by the union of 8, the two venæ innominatæ; and these by the junction 9 of internal jugular and subclavian vein at each side. 10. Greater vena azygos. 11. Termination of the lesser in greater vena azygos. 12. Receptaculum chyli; several lymphatic trunks are seen opening into it. 13. Thoracic duct, dividing opposite middle of dorsal vertebræ into two branches, which soon reunite; course of duct behind arch of aorta and left subclavian artery is shown by a dotted line. 14. The duct making its turn at root of the neck and receiving several lymphatic trunks previously to terminating in posterior aspect of junction of internal jugular and subclavian vein. 15. Termination of trunk of ductus lymphaticus dexter.

Fig. 61.

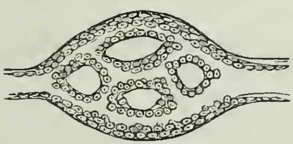
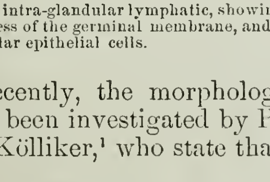


Diagram of a lymphatic gland, showing the intra-glandular network, and the transition from the scale-like epithelia of the extra-glandular lymphatics, to the nucleated cells of the intra-glandular.

the gland, becomes gradually thinner towards the afferent and efferent vessels, and passes continually into the ordinary epithelium.

Fig. 62.



Portion of the intra-glandular lymphatic, showing along the lower edge the thickness of the germinal membrane, and upon it the thick layer of glandular epithelial cells.

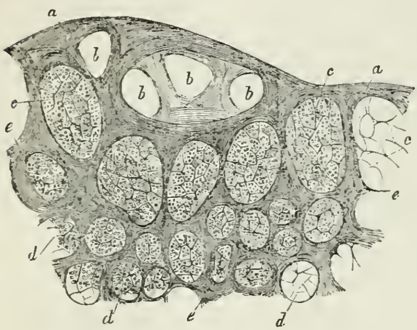
More recently, the morphology of these glands has been investigated by Prof. Brücke and Prof. Kölliker,[1] who state that each gland is enclosed in a fibrous

[1] Mikroskopische Anatomie, 2ter Band, S. 528, Leipzig, 1854; or Amer. edit. of Dr. Day's translation of his Human Histology, by Dr. Da Costa, p. 695, Philad., 1854.

sheath or capsule, which sends inwards a number of thin lamellæ, so as to constitute a tolerably regular areolated tissue in the whole gland. The alveoli, thus formed, are filled with a grayish-white pulp, which agrees, in all its characters, with that in the glands of Peyer, and is penetrated, like the latter, by a fine vascular plexus. The afferent

Fig. 63.

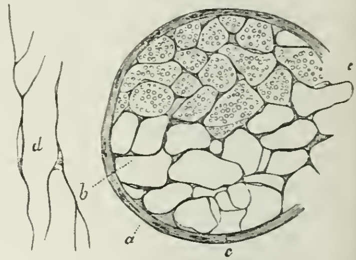
A



Section of Lymphatic Gland.

a, *a*. The fibrous tissue which forms its exterior. *b*, *b*. Superficial vasa inferentia. *c*, *c*. Larger alveoli near the surface. *d*, *d*. Smaller alveoli of the interior. *e*, *e*. Fibrous walls of the alveoli.

B



Section of one of the Alveoli of a Lymphatic Gland.

a, *a*. Its fibrous envelope. *b*, *b*. Prolongations from this, intersecting and subdividing the general cavity. *c*, *c*. Nuclei of the fibre-cells. *d*. Separate fibre-cells.

and efferent chyliferous vessels appear to communicate freely with these alveoli; and the fluid, brought to the glands by the former, must pass through their pulp before entering the latter.

It was before remarked, that the Peyerian glands may be regarded as belonging to the lacteal or lymphatic system. They resemble greatly in structure the mesenteric glands; and a greater number of chyliferous vessels may be traced from them during digestion than from other parts of the intestine. Brücke, too, found, that he could fill them by injection from the absorbents.

The *thoracic duct*, *g*, Fig. 55, and 13, Fig. 60, is formed by the junction of the chyliferous trunks with the lymphatic trunks from the lower extremities. The *receptaculum chyli*, already described, forms its commencement. After passing from under the diaphragm, the duct proceeds, in company with the aorta, along the right side of the spine, until it reaches the fifth dorsal vertebra; where it crosses over to the left side behind the œsophagus. It then ascends behind the left carotid artery; runs up to the interstice between the first and second vertebræ of the chest; where, after receiving the lymphatics, which come from the left arm and left side of the head and neck, it suddenly turns downwards, and terminates at the angle formed by the meeting of the subclavian and internal jugular vein of the left side.

To observe the chyliferous apparatus to the greatest advantage, it should be examined in an individual recently executed, or killed suddenly two or three hours after having eaten; or in an animal, destroyed for the purpose of experiment, under similar circumstances. The lacteals are then filled with chyle, and may be readily recognised, especially if the thoracic duct has been previously tied. These vessels were unknown to the ancients. The honour of their discovery is due to Gaspard Aselli,[1] of Cremona, who, in 1622, at the solicitation of some friends, undertook the dissection of a living dog, which had just eaten, in order to demonstrate the recurrent nerves. On opening the abdomen, he perceived a multitude of white, very delicate filaments crossing the mesentery in all directions. At first, he took them to be nerves; but having accidentally cut one, he saw a quantity of a white liquor exude, analogous to cream. Aselli also noticed the valves, but he fell into an important error regarding the destination of the lacteals; believing them to collect in the pancreas, and from thence proceed to the liver. In 1628, the human lacteals were discovered. Gassendi[2] had no sooner heard of the discovery of Aselli, than he spoke of it to his friend Nicholas-Claude-Fabrice de Peiresc, senator of Aix; who seems to have been a most zealous propagator of scientific knowledge. He immediately bought several copies of the work of Aselli, which had only appeared the year previously; and distributed them amongst his professional friends. Many experiments were made upon animals, but the great desire of De Peiresc was, that the lacteals should be found in the human body. Through his interest, a malefactor, condemned to death, was given up, a short time before his execution, to the anatomists of Aix; who made him eat copiously; and, an hour and a half after execution, opened the body, in which, to the great satisfaction of De Peiresc, the vessels of Aselli were perceived in the clearest manner. Afterwards, in 1634, John Wesling[3] gave the first graphic representation of them as they exist in the human body; and subsequently pointed out more clearly than his predecessors the thoracic duct and lymphatics. Prior to the discovery of the chyliferous and lymphatic vessels, the veins, which arise in immense numbers from the intestines, and, by their union with other veins, form the vena porta, were esteemed the agents of absorption; and, even at the present day, they are considered, by some physiologists, to participate with the chyliferous vessels in the function;—with what propriety we shall inquire hereafter.

2. CHYLE.

The chyle, as it circulates in the chyliferous vessels, has only been submitted to examination in comparatively recent times. It varies in different parts of its course. The best mode of obtaining it is to feed an animal; and, when digestion is in full progress, to strangle it, or divide the spinal marrow beneath the occiput. The thorax must then be opened through its whole length, and a ligature be passed round the aorta, œsophagus, and thoracic duct, as near the neck as possible. If the ribs of the left side be now turned back or broken, the thoracic duct is observed lying against the œsophagus. By detaching the upper part, and cutting into it, the chyle flows out. A small quantity only is thus obtained; but, if the intestinal canal and chyliferous vessels be repeatedly pressed upon, the flow may be sometimes kept up for a quarter of an hour. It is obviously impossible, in this way, to obtain

[1] De Lactibus seu Lacteis Venis, &c., Mediol., 1627; also, in Collect. Oper. Spigelii, edit. Van der Linden; and in Manget. Theatr. Anatom.
[2] Vita Peirescii, in Op. omnia, v. 300.
[3] Syntagm. Anatom., viii. 170.

the chyle pure; inasmuch as the lymphatics, from various parts of the body, are constantly pouring their fluid into the thoracic duct.

From the concurrent testimony of various experimenters, chyle is a liquid of a milky-white appearance; limpid and transparent in herbivorous animals, but opaque in the carnivorous; neither viscid nor glutinous to the touch; of a consistence, varying somewhat according to the nature of the food; a spermatic smell; sweet taste, not dependent on that of the food; neither acid nor alkaline: and of a specific gravity greater than distilled water, but less than the blood. Magendie,[1] Tiedemann and Gmelin,[2] and Müller,[3] however, state it to possess a saline taste; to be clammy on the tongue; and sensibly alkaline. Its milky colour is generally supposed to be owing to oily matter which occurs in it in the form of globules of various sizes, from $\frac{1}{25000}$th to $\frac{1}{2000}$th of an inch in diameter, and which are more abundant in the chyle of man and of the carnivora, than in that of the herbivora. Mr. Gulliver[4] has, however, affirmed, that the colour is due to an immense multitude of minute particles, which he regards as forming the matrix or *molecular base* of the chyle. These are generally spherical and extremely small,—their diameter being estimated at from $\frac{1}{36000}$th to $\frac{1}{24000}$th of an inch. They are of a fatty nature, and their number appears to be dependent upon the amount of fatty matter in the food. Their fatty nature is shown by their solubility in ether, and, when the ether evaporates, by their forming drops of oil. As, however, they do not run together, it has been suggested, that each molecule consists of oil coated with albumen, a view which is supported by the fact, that when water or dilute acetic acid is added to chyle, many of the molecules are lost sight of, and oil drops appear in their place; as if the envelopes of the molecules had been dissolved, and their oily contents had run together.[5]

The chemical character of the chyle of animals has been examined by Emmert,[6] Vauquelin,[7] Marcet,[8] Prout,[9] Simon,[10] Nasse,[11] and Lassaigne;[12] and is found to resemble greatly that of the blood. In a few minutes after its removal from the thoracic duct it becomes solid; and, after a time, separates, like the blood, into two parts; a coagulum, and a liquid. The coagulum is an opaque white substance; of a slightly pink hue; insoluble in water; but readily soluble in the alkalies, and alkaline carbonates. M. Vauquelin regards it as fibrin in an imperfect state, or as intermediate between that principle and albumen; but

[1] Précis, &c., ii. 172.

[2] Die Verdauung nach Versuchen, i. 353, Heidelb., 1826; or French translation, by Jourdan, Paris, 1827.

[3] Elements of Physiology, by Baly, p. 258, London, 1838.

[4] Gerber's General Anatomy, by Gulliver, Appendix, p. 88, London, 1842.

[5] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 210, Philad., 1853.

[6] Annales de Chimie, tom. lxxx. p. 81.

[7] Ibid., lxxx. 113; and Annals of Philosophy, ii. 220.

[8] Medico-Chirurg. Transactions, vol. vi. 618, London, 1815.

[9] Thomson's Annals of Philosophy, xiii. 121, and 263.

[10] Animal Chemistry, Sydenham Soc. edit., p. 354, London, 1845, or Amer. edit., Philad., 1846.

[11] Wagner's Handwörterbuch, n. s. w., i. 235, art. Chyle; and Simon. op. cit.

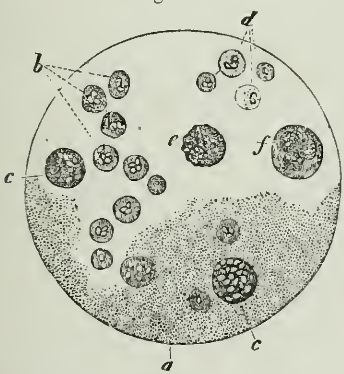
[12] Journ. de Chimie Méd., p. 348, Paris, 1853; and Scherer, in Canstatt's Jahresbericht, 1853, p. 111; and Day, Brit. and Foreign Med.-Chir. Rev., July, 1855, p. 217.

M. Brande[1] thinks it more closely allied to the caseous matter of milk than to fibrin. The analyses of Drs. Marcet and Prout agree, for the most part, with that of M. Vauquelin. The existence of fibrin in it can scarcely be doubted.

Like blood, again, chyle often remains for a long time in its vessels without coagulating, but coagulates rapidly on being removed from them.[2]

Dr. Prout has detailed the changes, which the chyle experiences in its passage along the chyliferous apparatus. In each successive stage, its resemblance to blood was found to be increased. Another point of analogy with blood is the fact, observed by Mr. Bauer,[3] and subsequently by MM. Prévost and Dumas,[4] and others, that the chyle, when examined by the microscope, contains globules or corpuscles; differing from those of the blood in their being of a smaller size, the average being $\frac{1}{4600}$th of an inch, and devoid of colouring matter.

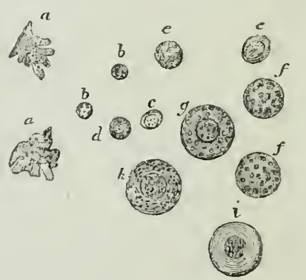
Fig. 64.



Fluid from a Mesenteric Gland of a Rabbit, when white Chyle was present in the Lacteals.

a. Molecular base. *b, c, d,* &c. Various organic corpuscles. *b.* Appearance of the majority of corpuscles. The contained granules are most numerous and coarse in the largest ones, but almost entirely disappear under the action of acetic acid, which thereby discloses an appearance of one or two nuclei. The majority of the corpuscles are either large or small, and but few of intermediate size. *d.* Exhibits the effect of acetic acid in rendering the corpuscles more clear and their nuclei more distinct. *e.* Large lymph-corpuscle, showing well the granulated border. *f.* Large corpuscle, apparently enclosing three smaller ones, each of which has the granulated character. This appearance of enclosed cells is not common.—Magnified 300 diameters.

Fig. 65.



Chyle-Corpuscles in various Phases.

a, a. Stellate form occasionally seen after escape of their contents. *b, b.* Free nuclei. c. A nucleus surrounded by a few granules. *d, e.* Small cells, some with distinct nucleus. *f, g.* Larger cells, one with a visible nucleus. *h.* Similar cell after addition of water. *i.* Similar cell after addition of acetic acid.

The nature and source of these globules, as well as of those of the lymph which resemble them in all respects, are not determined. They have been supposed to be the nuclei or primordial cells from which all the tissues originate,[5] of which there is no sufficient evidence: and to be the source of the blood-corpuscle, which—as hereafter shown—is probably the case. These corpuscles—it has been generally conceived—are formed mainly, if not wholly, in the mesenteric ganglia;

[1] Phil. Transact. for 1812.
[2] Bouisson, Gazette Médicale de Paris, 1844.
[3] Sir E. Home, Lectures on Comp. Anat., iii. 25.
[4] Biblioth. Universelle de Genève, p. 221, Juillet, 1821.
[5] Gulliver, in Gerber's Anatomy, p. 83, note.

and the recent researches of Virchow, Brücke, Donders, and Kölliker, confirm the view, that the principal origin of the cellæform elements of the chyle are formed in the lymphatic glands. The last mentioned observer,[1] with H. Müller, found in all the chyliferous vessels, proceeding from the Peyerian glands, a considerable amount of colourless cells: the chyle, however, from the other vessels of the small intestine, not connected with these glands, also contained cells,—in general, however, in smaller number; but no cellæform elements could be detected in the lymph proceeding from the much distended lymphatic vessels of the liver. Upon the supposition, therefore,—as Kölliker remarks—that the solitary follicles of the small and large intestine communicate with lymphatic vessels, these facts would appear to correspond with the hypothesis, that the lymphatic glands and the analogous follicles of the intestines are the only sites of formation of lymph cells. On the other hand, he invariably found in the large lymphatics of the spermatic cord of the bull, close to the epididymis, in several very carefully examined cases, a small number of cells which could not be distinguished from lymph corpuscles; and he, therefore, suggests, whether the epithelial cells of the smaller lymphatics may not participate in this cell-formation more than has hitherto been believed.

Although chyle has essentially the same constituents, whatever may be the food taken, and separates equally into a clot and serous portion, the character of the aliment may have an effect upon the relative quantity of those constituents, and thus exert an influence on its composition. That it scarcely ever contains adventitious substances will be seen hereafter; but it is obvious, that if an animal be fed on diet contrary to its nature, the due proportion of *perfect* chyle may not be formed; and that, in the same way, different alimentary articles may be very differently adapted for its formation. MM. Leuret and Lassaigne,[2] indeed, affirm, that in their experiments they found the chyle differ more according to the nature of the food than to the animal species; but that, contrary to their expectation, the quantity of fibrin in it bore no relation to the more or less nitrogenized character of the aliment. They assign it, as constituents, fibrin, albumen, fatty matter, soda, chloride of sodium, and phosphate of lime.

Messrs. Tiedemann and Gmelin have communicated the following data in regard to the influence of diet on the chyle. The experiments were made on dogs, and the chyle was taken from the thoracic duct. *First.* After taking cheese, the chyle coagulated very slightly. The clot was little more than a pale red transparent film, and the serum slightly milky. It contained water, 950·3; clot, 1·71: residue of serum, 48·0. *Secondly.* After the use of starch, the chyle was of a pale yellowish-white colour, and coagulated rapidly. It contained water 930·0; clot and residue of serum, 70·0. The clot was of a pale red colour. *Thirdly.* After taking flesh, and bread and milk, it was of a reddish-white colour, and coagulated rapidly, the clot being of a pale red tint, and the serum very milky. It consisted of water, 915·3;

[1] Zeitschrift für Wissensch. Zoolog. vii. 182; and Quarterly Journal of Microscopical Science, July, 1855, p. 291.

[2] Recherches sur la Digestion, Paris, 1825.

clot, 2·7; residue of serum, 83·8. *Fourthly.* After the use of milk it presented a milky appearance, and the clot was transparent, and of a pale red colour. *Fifthly.* After bread and milk, it contained water, 961·1; clot 1·9; residue of serum, 37·0. *Sixthly.* After flesh, bread, and milk, when the gall duct had been tied, it was of a yellowish red colour; coagulated firmly, separating into a bright red clot, and turbid yellow serum; and contained water, 933·5; clot, 5·6; residue of serum, 60·9.[1]

The chief object of Dr. Marcet's experiments was to compare the chyle from vegetable, with that from animal food, in the same animal. The experiments made on dogs led him to the following results. The specific gravity of the serous portion is from 1·012 to 1·021, whether it be formed from animal or vegetable diet. Vegetable chyle, when subjected to analysis, furnishes three times more carbon than animal chyle. The latter is highly disposed to become putrid; and this change generally commences in three or four days; whilst vegetable chyle may be kept for several weeks, and even months, without being putrid.[2] Putrefaction attacks rather the coagulum of the chyle than its serous portion. The chyle from animal food is always milky; and, if kept at rest, an unctuous matter separates from it, similar to cream, which swims on the surface. The coagulum is opaque, and has a rosy tint. On the other hand, chyle from vegetable food is almost always transparent, or nearly so, like ordinary serum. Its coagulum is nearly colourless, and resembles an oyster; and its surface is not covered with the substance analogous to cream. M. Magendie,[3] too, remarks, that the proportion of the three substances, into which chyle separates when left at rest;—namely, the fatty substance on the surface, the clot, and the serum, varies greatly according to the nature of the food;—that the chyle, proceeding from sugar, for example, has very little fibrin; whilst that from flesh has more; and that the fatty matter is extremely abundant when the food contains fat or oil; whilst scarcely any is found if the food contains no oleaginous matter.

Lastly:—the attention of Dr. Prout[4] has been directed to the same comparison. He found, on the whole, less difference between the two kinds of chyle than had been noticed by Dr. Marcet. In his experiments, the serum of chyle was rendered turbid by heat, and a few flakes of albumen were deposited; but, when boiled, after admixture with acetic acid, a copious precipitation ensued. To this substance, which thus differs slightly from albumen, Dr. Prout gave the inexpressive name of *incipient albumen.* The following is a comparative analysis, by him, of the chyle of two dogs, one of which was fed on animal, and the other on vegetable substances. The quantity of pure albumen, it will be observed, was much less in the latter case.

[1] Tiedemann and Gmelin, Verdauung u. s. w., 2 B. S. 75, Heidelb. und Leipz., 1827.

[2] M. Thénard has properly remarked, that the difference in the time of putrefaction of these two substances, appears very extraordinary. It is, indeed, inexplicable. Traité de Chimie Élémentaire, &c., 5ème édit., Paris, 1827.

[3] Op. citat., p. 174.

[4] Annals of Philosophy, xiii. 22, and Bridgewater Treatise, Amer. edit., p. 272, Philad., 1834.

	Vegetable Food.	Animal Food.
Water	93·6	89·2
Fibrin	0·6	0·8
Incipient albumen	4·6	4·7
Albumen, with a red colouring matter	0·4	4·6
Sugar of milk	a trace.	
Oily matter	a trace.	a trace.
Saline matters	0·8	0·7
	100·0	100·0

The difference between the chyle from food of such opposite character, as indicated by these experiments, is insignificant, and indicative of the great uniformity in the action of the agents of absorption. Researches by Messrs. Macaire and Marcet,[1] tend, indeed, to establish the fact, that the chyle and the blood of herbivorous and carnivorous quadrupeds are identical in their composition, in as far, at least, as regards their ultimate analysis. They found the same proportion of nitrogen in it, whatever kind of food the animal consumed habitually; and this was the case with the blood, whether of the carnivora or herbivora; but it contained more nitrogen than the chyle. These results are not so singular, now that we know that the animal and vegetable compounds of protein are almost identical in composition.

All the investigations into the nature of the chyle exhibit the inaccuracy of the view of Roose,[2] that chyle and milk are identical.[3]

With regard to the precise quantity of chyle, formed after a meal, we know nothing definite. When digestion is not going on, there can of course be none formed except from the digestion of the secretions of the digestive tube itself; and, after an abstinence of twenty-four hours, the contents of the thoracic duct are chiefly lymph. During digestion, the quantity formed will bear some relation to the amount of food taken, the nutritive qualities of the food, and the digestive powers of the individual. M. Magendie,[4] from an experiment made on a dog, estimated, that at least half an ounce was conveyed into the mass of blood, in that animal, in five minutes: and the flow was kept up, but much more slowly, as long as the formation of chyle continued. In experiments on a cat, Professor F. Bidder[5] found the amount that passed through the thoracic duct in the twenty-four hours, to be in proportion to the weight of the body as 1 to 5.34; or about that which—as elsewhere shown—the mass of blood has been generally conceived to bear to the weight of the body. In dogs, the proportion was as 1 to 6.66. It is difficult, however, to establish an average amount where so many elements have to enter into the calculation, and so much variation must occur, according to the greater or less amount of aliment taken, and numerous other circumstances;[6] but that so large a quantity passes as is stated by these observers, almost exceeds belief.

[1] Mémoir. de la Société de Physique et de l'Histoire Naturelle de Genève, v. 389.

[2] Weber's Hildebrandt's Handbuch der Anatomie, i. 102. Braunschweig, 1830.

[3] See, on the whole subject of the chyle, Lehmann, Lehrbuch der Physiologischen Chemie, ii. 271, Leipz., 1850; or Amer. edit. of Dr. Day's translation, by Dr. Robt. E. Rogers, ii. 17. Philad., 1855.

[4] Op. citat., ii. 183.

[5] Müller's Archiv. für Anat., s. 46, Berlin, 1845, and Bidder and Schmidt, Die Verdauungssäfte und der Stoffwechsel. s. 283, Mitau und Leipz., 1852.

[6] Prof. Th. L. W. Bischoff, Müller's Archiv., No. 6, s. 125, Berlin, 1846.

3. PHYSIOLOGY OF CHYLOSIS.

The facts referred to—regarding the anatomical arrangement of the chyliferous radicles and mesenteric glands—will sufficiently account for the obscurity of our views on many points of chylosis. The difficulty in detecting the extremities of the chyliferous radicles has been the source of different hypotheses; and, according as the view of open mouths or of spongy gelatinous tissue has been embraced, the chyle has been supposed to enter immediately into the vessels, or to be received through the medium of this tissue; or, again, to pass through the parietes of the vessels by imbibition. Let it be borne in mind, however, that the action of absorption is seen only by the "mind's eye;" and that chyle does not seem to exist anywhere but in the chyliferous vessels. In the small intestine, we see a chymous mass, possessing all the properties we have described, but containing nothing resembling true chyle; whilst, in the smallest lacteal that can be detected, it always possesses the same essential properties. Between this imperceptible portion of the vessel, then, and its commencement—including the latter—the elaboration must have been effected. MM. Leuret and Lassaigne,[1] indeed, affirm that they have detected chyle in the chymous mass within the intestine, by the aid of the microscope. They state, that globules appeared in it similar to those that are contained in chyle, and that their dissemination amongst so many foreign matters alone prevents their union in perceptible fibrils. These globules they regard as true chyle—for the reason, that they observed similar globules in artificial digestions; and, on the other hand, never detected them in the digestive secretions. In their view, consequently, chyliferous absorption is confined to the separation of chyle, ready formed in the intestine, from the excrementitious matters united with it. But we must have stronger evidence to set aside the overwhelming testimony in favour of an action of selection and elaboration by the absorbents of all organized bodies—vegetable as well as animal. The nutriment of the vegetable may exist in the soil and the air around it; but it is subjected to a vital agency the moment it is laid hold of, and is decomposed to be again combined to form sap. A like action is doubtless exerted by the chyliferous radicles;[2] and hence all the modes of explaining this part of the function, under the supposition of their being passive, mechanical tubes, are inadequate. Boerhaave[3] affirmed, that the peristaltic motion of the intestines has a considerable influence in forcing chyle into the mouths of the chyliferous vessels; and Brücke is of opinion, that the contraction of the muscular fibres of the canal are concerned in the entrance of the chylous matter into the perforated epithelial cells which he depicts;[4] whilst Dr. Young[5] is disposed to ascribe the whole effect to capillary attraction; and he cites the lachrymal duct as an analogous case, the contents of which, he conceives—and we think with propriety—are entirely propelled in this manner.

[1] Recherches Physiologiques et Chimiques, pour servir à l'Histoire de la Digestion, p. 60, Paris, 1825.

[2] F. Arnold, Lehrbuch der Physiologie des Menschen, Zürich, 1836–7; noticed in Brit. and For. Med. Review, Oct. 1839, p. 479.

[3] Prælect. Academ. in Prop. Instit. Rei Med., § 103.

[4] Page 209.

[5] Medical Literature, p. 42, Lond., 1813.

The objections to these views, as regards the chyliferous vessels, are sufficiently obvious. The chyle must, according to them, exist in the intestines; and, if that of Boerhaave were correct, we ought to be able to obtain it from the chyme by pressure. As the chyle is not present, ready formed, in the intestine, the explanations by imbibition and by capillary attraction are equally inadmissible. There is no analogy between the cases of the lachrymal duct and the chyliferous vessels; even if it were admitted, that the latter have open mouths, which is not the case. In another part of this work, it was affirmed, that the passage of the tears through the puncta lachrymalia, and along the lachrymal ducts, is one of the few cases in which capillary attraction can be invoked, with propriety, for the explanation of functions executed by the human frame. In that case, there is no conversion of the fluid. It is the same on the conjunctiva as in the duct; but, in the case of the chyliferous vessels, a new fluid is formed: there must, therefore, have been an action of selection exerted; and this very action would be the means of the entrance of the new fluid into the mouths of the lacteals. If, therefore, we admit, in any form, the doctrine of capillary tubes, it can only be, when taken in conjunction with that of the elaborating agency. "As far as we are able to judge," says Dr. Bostock,[1] "when particles, possessed of the same physical properties, are presented to their mouths (the lacteals), some are taken up, while others are rejected; and if this be the case, we must conceive, in the first place, that a specific attraction exists between the vessel and the particles, and that a certain vital action must, at the same time, be exercised by the vessel, connected with, or depending upon, its contractile power, which may enable the particles to be received within the vessel, after they have been directed towards it. This contractile power may be presumed to consist in an alternation of contraction and relaxation, such as is supposed to belong to all vessels that are intended for the propulsion of fluids, and which the absorbents would seem to possess in an eminent degree." This is specious; but it would be not the less hypothetical if the chyliferous vessels had open mouths. By other physiologists, absorption is presumed to be effected by virtue of the peculiar *sensibility* or *insensible organic contractility* or *irritability* of the mouths [?] of the absorbents; but these terms, as M. Magendie[2] has remarked, are the mere expression of our ignorance, regarding the nature of the phenomenon. The separation of the chyle is, doubtless, a chemical process; seeing that there must be both an action of decomposition and recomposition; but it is not regulated solely by the same laws that govern inorganic chemistry.

Professor Goodsir,[3] with almost all modern physiologists, has referred the function to the agency of cells. Having fed a dog with oatmeal, butter, and milk, he examined the intestinal villi three hours afterwards; when the chyliferous vessels were turgid with chyle, and the intestine was full of milky chyme mingled with a bilious-looking fluid. In the white portion of the fluid, which was situate principally towards

[1] Physiology, edit. cit., 622, Lond., 1836. [2] Précis, &c., ii. 179.
[3] Edinb. New Philosophical Journal, July, 1842; and Anatomical and Pathological Observations, p. 4, Edinb., 1845.

the mucous membrane, numerous epithelium cells were found; some of which had evidently—from their form—been detached from the surface of the villi; whilst others had been thrown off from the interior of the follicles of Lieberkühn. The villi were turgid, and destitute of epithelium except at their bases. Each villus was covered by a very fine, smooth membrane, continuous with what Mr. Bowman terms the "basement membrane" of the mucous surface, which is reflected into the follicles. The villi were semitransparent, except at their free or bulbous extremities, where they were white and nearly opaque. The summit of each villus was crowded beneath the enveloping membrane with a number of perfectly spherical vesicles, varying in size from $\frac{1}{1000}$th to $\frac{1}{2000}$th of an inch; the matter in the interior of which had an opalescent, milky appearance. At the part where the vesicles approached the granular texture of the substance of the villus, minute granular or oily particles were situate in great numbers. The trunks of two lacteals could be easily traced up the centre of each villus; and as they approached the vesicular mass, they subdivided and looped; but in no instance could they be seen to communicate directly with any of the vesicles. These vesicles, in Mr. Goodsir's opinion, can scarcely be considered in any other light than cells, whose lives have but a very brief duration, which select from, and appropriate the materials in contact with the surface of the villi into their own substance, and then liberate them, by solution or disruption of the cell-wall, in a situation where they can be absorbed by the lacteals. When the intestine contains no more chyme, the development of new vesicles ceases; the lacteals empty themselves, and the villi become flaccid. During the interval of repose, the epithelium is renewed for the protection of the surface of the villi, and for the secretion function of the follicles of Lieberkühn. It is considered by Mr. Goodsir, that the epithelium cells have their origin in certain nuclei, which he has detected scattered through the basement membrane.

These views were embraced by Dr. Carpenter; but they are by no means established. It is denied, indeed, by Reichert,[1] from his own and Bidder's observations, that the epithelium is ever so shed from the digestive canal, in or after any act of digestion, as to leave any portion of the subjacent mucous membrane uncovered or raw; and Prof. E. H. Weber[2] distinctly observed the chyliferous vessels filled with chyle, although the mucous membrane was covered with epithelium. The materials of the chyle, therefore, to enter the vessels must have passed through the epithelium. During absorption, he noticed the prismatic cells of the cylinder epithelium experiencing change of form and colour, and in rabbits and frogs becoming tumid, and containing chyle corpuscles. In man, beneath the epithelium is a second layer of cells, which are neither conical, cylindrical, nor prismatic, but round; many of which are filled with an opaque white; and others with a transparent, oleaginous fluid; so that different cells appeared to absorb different fluids. Dr. Carpenter, indeed, now regards Mr. Goodsir's views as to the nature of those cells to be erroneous, "for several excellent observers," he says, "agree in regarding them as the proper epithe-

[1] Müller's Archiv., 1844. [2] Ibid., s. 401, Berlin, 1847.

lium cells of the villi, which are not thrown off as Prof. Goodsir believed, but so completely change their aspect in consequence of the imbibition of oleaginous fluid (Fig. 59), that they cease to be recognizable as such, unless their intermediate stages be traced. It may then," he adds, "be stated with some confidence, that the epithelium cells covering the extremities of the villi, are the real instruments in the selection and absorption of the materials of the chyle; and that, drawing these into their own cell-cavities, they subsequently deliver them up to the lacteals, by which they are carried towards the centres of the circulation."[1]

It has already been said, that chyle always possesses the same essential properties; that it may vary slightly according to the food, and the digestive powers of the individual; but rarely if ever contains any adventitious substance,—the function of the chyliferous vessels being restricted to the formation of chyle. The facts and arguments, in favour of this view of the subject, will be given hereafter.

The course of the chyle is, as we have described, along the chyliferous vessels, and through the mesenteric glands into the receptaculum chyli or commencement of the thoracic duct; along which it passes into the subclavian vein. The chief causes of its progression are,—first of all, the inappreciable action, by which the chyliferous vessels form and receive the chyle into them. This formation being continuous, the fresh portions must propel those already in the vessels towards the mesenteric glands, in the same way as the ascent of sap in plants, during the spring, appears to depend on the constant absorbing action of the roots.[2] The vessels themselves, too, are contractile:[3] such was the opinion of Messrs. Sheldon,[4] Schneider, Cruikshank,[5] and J. Muller. M. Mandl[6] affirms, that it can no longer be doubted; and that the irritability continues even for several hours after death. M. Mojon[7] considers, that when the longitudinal fibres, which he has observed in the lymphatics, contract, they draw one sphincter nearer to another, whilst the oblique fibres diminish the diameter. All these fibres, taking their *point d'appui* in the circular fibres, dilate the superior sphincters by drawing the circumference downwards. By this method, the fluid that enters a lymphatic irritates the vessel, which contracts upon itself, diminishes its cavity, and sends on the fluid through the open sphincter. A kind of peristaltic action, he conceives,—and in this view he is confirmed by MM. Lacauchie,[8] Gruby, and Delafond,[9]—exists in the lymphatics similar to that of the intestines, which may be observed very distinctly in the lacteal vessels of the mesentery of animals, if opened two or three hours after they have been well fed. In the veins of the wing of the bat, a regular rhythmical movement has been observed by Mr. Wharton Jones,[10] the result of their own contractile power; and the existence of such a movement of the veins of a part

[1] Principles of Human Physiology, Amer. edit., p. 136, Philad., 1855.
[2] Breschet, Le Système Lymphatique, Paris, 1836.
[3] Müller's Handbuch, u. s. w., and Baly's translation, i. 284, Lond., 1838.
[4] History of the Absorbent System, p. 28, Lond., 1784. [5] Op. citat., c. 12.
[6] Manuel d'Anatomie Générale, p. 211, Paris, 1843.
[7] Journ. de la Société des Sciences Physiques, etc., Nov. 1833.
[8] Comptes Rendus, 15 Mai, 1843. [9] Ibid., 5 Juin, 1843.
[10] Proceedings of the Royal Society, Feb. 1852, and Philosophical Transactions for 1852, p. 131.

as an auxiliary propulsive force, Dr. Carpenter[1] thinks, obviously strengthens the probability of its occurrence in the lymphatics as the principal propelling power, where no central impelling organ exists; "just as a like movement is seen in the bloodvessels of such of the lower invertebrata as have no heart."

In the absence of more direct observation it was argued that the lacteals and lymphatics are possessed of a power of contraction for the following reasons:—*First.* They are small; and tonic contractions are generally admitted in all capillary vessels. *Secondly.* The ganglions or glands, which cut them at intervals, would destroy the impulse given by the first action of the radicles; and hence require some contraction in the vessels to transport the chyle from one row of these ganglions to another. *Thirdly.* If a chyliferous vessel be opened in a living animal, the chyle spirts out, which could not be effected simply by the absorbent action of the chyliferous radicles; and, *Fourthly*, in a state of abstinence, these vessels are found empty; proving, that notwithstanding there has been an interruption to the action of chylous absorption, the whole of the chyle has been propelled into the receptaculum chyli. It is obvious, however, that most of these reasons would apply as well to the elasticity as to the muscularity of the outer coat of these vessels.[2] A more forcible argument is derived from an experiment by Lauth.[3] He killed a dog towards the termination of digestion; and immediately opened its abdomen, when he found the intestines marbled, and the chyliferous vessels filled with chyle. Under the stimulation of the air, the vessels began to contract, and, in a few minutes, were no longer perceptible. The result he found to be the same, whenever the dissection was made within twenty-four hours after death; but, at the end of this time, the irritability of the vessels was extinct; and they remained distended with chyle, notwithstanding the admission of air. Kölliker[4] found, too, that when the wire of an electro-magnetic apparatus was applied to some well filled lymphatics on the skin of a dog's foot soon after the leg had been removed by amputation, their diameter was diminished at least one half; and this did not occur suddenly, but in the course of between half a minute and a minute.

These experiments and observations led to a deduction, in the absence of less direct proof, scarcely doubtful;—that the chyliferous vessels possess a contractile action, by the aid of which the chyle is propelled along them. In addition to these propelling causes, the pulsation of the arteries in the neighbourhood of the vessels, and the pressure of the abdominal muscles in respiration have been invoked. The former has probably less effect than the latter. It is not, indeed, easy to see how it can be possessed of any. Of the agency of the latter we have experimental evidence. If the thoracic duct be exposed in the neck of a living animal, and the course of the chyle be observed, it will be found accelerated at the time of inspiration, when the depressed diaphragm forces down the viscera, or when the abdo-

[1] Principles of Human Physiology, Amer. edit., p. 158, Philad., 1854.
[2] Adelon, Physiologie, etc., iii. 31.
[3] Essai sur les Vaisseaux Lymphat., Strasb., 1824.
[4] Kölliker and Siebold's Zeitschrift, 1849.

men of the animal is compressed by the hands. We shall find, too, hereafter, that the mode in which the thoracic duct opens into the subclavian exerts considerable effect on the progress of the chyle. We have reason to believe that its course is slow. It has been already stated, that in an experiment on a dog, which had eaten animal food at discretion, M. Magendie[1] found half an ounce of chyle discharged from an opening in the thoracic duct in five minutes. Still, as he judiciously remarks, the velocity will be partly dependent upon the quantity of chyle formed. If much enters the thoracic duct, it will probably proceed faster than under opposite circumstances. In the commencement of the thoracic duct it becomes mixed with lymph; and under the head of lymphatic absorption we shall show how they proceed together into the subclavian, and the effect produced by the circumstances under which the thoracic duct opens into that venous trunk.

It has been a subject of inquiry, whether chyle varies materially in different parts of its course; and what is the precise modification, impressed upon it by the action of the mesenteric glands. The experiments of Reuss, Emmert,[2] and others, seem to show, that when taken from the intestinal side of the glands it is of a yellowish-white colour; does not become red on exposure to the air, and coagulates but imperfectly, depositing only a small, yellowish pellicle. It is said, indeed, that chyle, drawn from the chyliferous vessels, which traverse the intestinal walls, contains albumen in a state of solution, but no fibrin, and abounds in oleaginous matter; whilst that from the other side of the glands, and near the thoracic duct, is of a reddish hue; contains chyle globules; coagulates entirely, and separates into a clot and serum. M. Vauquelin,[3] too, affirms, that it acquires a rosy tint as it advances in the apparatus; and that the fibrin becomes gradually more abundant. These circumstances have given rise to the belief, that as it proceeds it becomes more and more animalized, or transformed into the nature of the being. This effect has generally been ascribed to the mesenteric glands; and it has been presumed by some to be produced by the exhalation of a fluid into their cells from the numerous blood-vessels with which they are furnished. Others, again, consider, that the veins of the glands remove from the chyle every thing that is noxious; or purify it. From the circumstance, that the rosy colour is more marked on the thoracic, than on the intestinal side of the glands; that the fluid is richer in fibrin after having passed through those glands; and that the rosy colour and fibrin are less when the animal has taken a large proportion of food, MM. Tiedemann and Gmelin[4] infer, that it is to the action of the glands, that the chyle owes those important changes in its nature;—the fluid, in its passage through them, obtaining, from the blood circulating in them, new elements, which animalize it.

There is much probability in the view, that some nitrogenized material is secreted from the lining membrane of the chyliferous vessels,

[1] Précis, &c., ii. 183.
[2] Reil's Archiv., viii. s. 2; and Annales de Chimie, lxxx. 81.
[3] Annales de Chimie, lxxxi. 113; and Annals of Philosophy, ii. 220.
[4] Die Verdauung nach Versuchen, u. s. w., or Jourdan's translat., Paris, 1827.

in the mesenteric glands especially, through the agency of the nucleated cells described by Professor Goodsir, which may be a great agent in the changes effected on the chyle in its course. At the same time—as has been well observed[1]—an important source of fallacy attends all deductions founded upon the differences observed in the chyle in the several parts of its course through the lacteals,—which is, that we cannot be at all sure how far this may not be dependent upon an actual interchange of ingredients with the blood, by imbibition through the very thin parietes of the contiguous vessels. The whole question, as Dr. Carpenter properly remarked, offers a wide scope for farther inquiry.

The following table, slightly modified from one by Gerber,[2] exhibits concisely the relative proportions of the three main ingredients of the chyle—fat, albumen, and fibrin—in various parts of the absorbent system; and affords some idea of its change in the process of assimilation.

I. In the afferent or peripheral lacteals (from the intestines to the mesenteric glands).	*Fat* in maximum quantity (numerous fat or oil globules). *Albumen* in minimum quantity (few or no *chyle corpuscles*). *Fibrin* almost entirely wanting.
II. In the efferent or central lacteals (from the mesenteric glands to the thoracic duct).	*Fat* in medium quantity (fewer oil globules). *Albumen* in maximum quantity (*chyle corpuscles* very numerous, but imperfectly developed). *Fibrin* in medium quantity.
III. In the thoracic duct.	*Fat* in minimum quantity (fewer or no oil globules). *Albumen* in medium quantity (*chyle corpuscles* numerous and more distinctly cellular). *Fibrin* in maximum quantity.

In another place, various hypotheses, that have been indulged regarding the functions of the spleen, will be noticed. It is proper, however, to refer, here, to one which has been proposed by MM. Tiedemann and Gmelin. They consider the organ a dependent ganglion of the absorbent system, which prepares a fluid destined to be mixed with the chyle to effect its animalization; and assert, that the chyle coagulates little or not at all before it has passed through the mesenteric glands; but, after this, fibrin begins to appear, and is much more abundant after the addition of the lymph from the spleen, which contains a large quantity of fibrin. Before passing the mesenteric glands, the chyle contains no red particles; but it does so immediately afterwards, and more particularly after it is mixed with the lymph from the spleen, which abounds with them, and with fibrin. M. Voisin,[3] who, as we have seen, considers that the chyliferous vessels ramify in the substance of the liver, is of opinion that, by the action of the liver, a species of purification is produced in the chyle, by which the latter is better fitted to mingle with, and form part of, the blood; but neither his anatomical nor physiological views on the subject have met with much countenance.

Prior to the discovery of the chyliferous vessels, the mesenteric veins were regarded as agents of chylous absorption; and as these veins ter-

[1] Carpenter, Human Physiology, 2d Amer. edit., p. 426, Philad., 1845; and last Amer. edit., p. 156, Philad., 1855.

[2] Ibid., 2d edit. p. 427. [3] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.

minate in the vena porta, which is distributed to the liver, this last was considered the first organ of sanguification; and to impress upon the chyle a primary elaboration. In this view, the great size of the organ compared with the small quantity of bile furnished by it, and the exception, which the mesenteric veins and vena porta present to the rest of the venous system,—as well as the large size of the liver in the fœtus, although not effecting any biliary secretion, and the fact of its receiving immediately the nutritive fluid from the placenta were accounted for. The idea of the agency of the mesenteric veins is now nearly exploded, but not altogether so. There are yet physiologists, and of no little eminence, who esteem them participators in the functions of chylosis with the chyliferous vessels themselves.

Some of the arguments, based on fallacious data, used by these gentlemen, are:—*First.* The mesenteric veins form as much an integrant part of the villi of the intestine as the chyliferous vessels; and they have also, free orifices [?] in the cavity of the intestine. Lieberkühn,[1] by throwing an injection into the vena porta, observed the fluid ooze out of the villi of the intestine; and M. Ribes[2] obtained the same result by injecting spirit of turpentine coloured black. These experiments—it need hardly be said—are insufficient to establish the fact of open mouths. Situate, as those vessels are, in an extremely loose tissue, which affords them but little support, the slightest injecting force might be expected to rupture them. *Secondly.* Chyle has often been found in the mesenteric veins. Swammerdam asserts, that, having placed a ligature around these veins in a living animal, whilst digestion was goina on, he saw whitish, chylous striæ in their blood; and Tiedemann and Gmelin affirm, that they have often, in their experiments, observed the same appearance. If the fact of the identity of these striæ with chyle were well established, we should have to bend to the weight of evidence. This is not, however, the case. No other reason for the belief is afforded than their colour. The arguments against the mesenteric veins having the power of forming chyle we think irresistible. A distinct apparatus exists, which scarcely ever contains any thing but chyle; and consequently, it would seem unnecessary, that the mesenteric veins should participate in the function, especially as the fluid which circulates in them is most heterogeneous; and, as we shall see, a compound of various adventitious and other absorptions. Granting, however, that these striæ are true chyle, it would by no means follow absolutely, that it should be formed by the mesenteric veins. A communication may exist between the chyliferous vessels and these veins. Wallæus[3] asserts, that having placed a ligature on the lymphatic trunks of the intestine, chyle passed into the vena porta. Rosen, Meckel,[4] and Lobstein affirm, that by the use of injections they detected this inosculation. Lippi[5] states, that the chyliferous vessels have numerous

[1] Dissert. de Fabric. Villor. Intestin., Lugd. Bat., 1745.

[2] Mémoir. de la Société Médicale d'Emulation, viii. 621.

[3] Medica Omnia, &c., ad Chyli et Sanguinis Circul., Lond., 1660.

[4] Diss. Epist. ad Haller. de Vasis Lymph., &c., Berol., 1757; Nov. Exper. de Finibus Venarum et Vas. Lymph., Berol., 1772, and Manuel d'Anatomie, &c., French edit., by Jourdan, i. 179.

[5] Illustrazioni Fisiologiche e Patologiche del Sistema Linfatico-Chilifero, Firenze, 1825.

anastomoses with the veins, not only in their course along the mesentery before they enter the mesenteric glands, but also in the glands themselves. Tiedemann and Gmelin concur in the existence of this last anastomosis, and MM. Leuret and Lassaigne found that a ligature applied round the vena porta occasioned a reflux of blood into the thoracic duct. Professors Meckel, E. H. Weber, Rudolphi, and J. Müller doubt, however, the existence of an actual open communication between the lymphatics and minute veins in the glands. Meckel states, as a reason for his questioning this, that when the seminal duct of the epididymis of the dog is injected, the veins also are filled; and Müller[1] observes, that when glands are injected from their excretory duct, the small veins of the gland also frequently become filled with mercury; and the cases in which this occurred to him were always those in which the ducts had not been well filled,—their acini not distended. *Thirdly.* That the ligature of the thoracic duct has not always induced death, or has not induced it speedily; and, consequently, the thoracic duct is not the only route by which the chyle can pass to be inservient to nutrition. In an experiment of this kind by M. Duverney, the dog did not die for fifteen days. M. Flandrin repeated it on twelve horses, which appeared to eat as usual, and to maintain their flesh. On killing and opening them a fortnight afterwards, he satisfied himself that the thoracic duct was not double. Sir Astley Cooper performed the experiment on several dogs: the majority lived longer than a fortnight, and none died in the first two days; although, on dissection, the duct was found ruptured, and chyle effused into the abdomen. The experiments of M. Dupuytren have satisfactorily accounted for these different results. He tied the thoracic duct in several horses. Some died in five or six days, whilst others continued apparently in perfect health. In those that died in consequence of the ligature, it was impossible to throw any injection from the lower part of the duct into the subclavian. It was, therefore, presumable, that the chyle had ceased to be poured into the blood, immediately after the duct was tied. On the other hand, in those that remained apparently unaffected, it was always easy to send mercurial or other injections from the abdominal portion of the duct into the subclavian. The injections followed the duct until near the ligature, when they turned off, and entered large lymphatic vessels, which opened into the subclavian; so that, in these cases, the ligature of the thoracic duct did not prevent the chyle from passing into the venous system; and thus we can understand why the animals should not have perished.[2]

From every consideration, then, it appears that the chyliferous vessels are the sole organs concerned in chylosis; and we shall see presently, that they refuse the admission of other substances, which must, consequently, reach the circulation through a different channel.

The views of those who believe, that the absorption of the nutritive portion of most aliments takes place in the stomach,—fatty matters only being absorbed by the chyliferous vessels,—have been referred to elsewhere. M. Bernard, who properly ascribes to the liver a most

[1] Handbuch, u. s. w.; and Baly's translation, p. 273, Lond., 1838.
[2] Richerand's Élémens de Physiologie, edit. cit., p. 90.

important assimilating function, agrees with those gentlemen, that albuminous and saccharine matters are taken up by the gastro-intestinal veins, by which they are conveyed to that organ; and that the chyliferous vessels absorb only fat. Chyle, in other words, he regards as lymph holding in suspension emulsified fat;[1] and all these substances, according to him, pass into veins and lacteals by a simple act of endosmose. It has been already argued, however, that the formation of chyle—and the same may be said of that of lymph—is an action of selection and elaboration,—the product being always essentially the same; and exhibiting the same constituents, although their proportions vary within restricted limits. Fat, moreover, can readily pass into the intestinal bloodvessels, and has been detected in them in such quantity,—that, according to Bruch,[2] the superficial capillary network presents, at times, an opalescent whiteness. Moreover, the experiments of Matteucci[3] have sufficiently shown, that no special arrangement of chyliferous vessels is required for the absorption of fat, seeing that if an emulsion be put into an intestine, and the intestine be plunged into a weak alkaline solution, the latter becomes turbid from the passage of the oily matter through the membrane; so that it can be readily understood, that fatty matter may be found both in the chyliferous vessels and in the lymphatics.

b. *Absorption of Drinks.*

It has been already stated, that a wide distinction exists between the gastric and intestinal operations that are necessary in the case of solid and of thin liquid food. Whilst the former is converted into chyme and passes into the small intestine, to have its chylous part separated from it; the latter is usually absorbed from the stomach or small intestine.

Fig. 66.

Villi of the Human Intestine, with their Capillary Plexus injected.

The chyliferous vessels, we have seen, are agents and exclusive agents of the absorption of chyle—the nutritive product from the digestion of solids. What, then, are the agents of the absorption of liquids? There are but two sets of vessels on which we can rest for a moment. These are the lacteals or lymphatics of the digestive tube; and the veins of the same canal. But, it has been seen, the chyliferous vessels refuse the admission of everything but chyle. It would necessarily follow, then, that the absorption of liquids must be a function of the veins. Such is the conclusion of most physiologists, and on inferences that are logical. The view is not, however, universally admitted; some assigning the

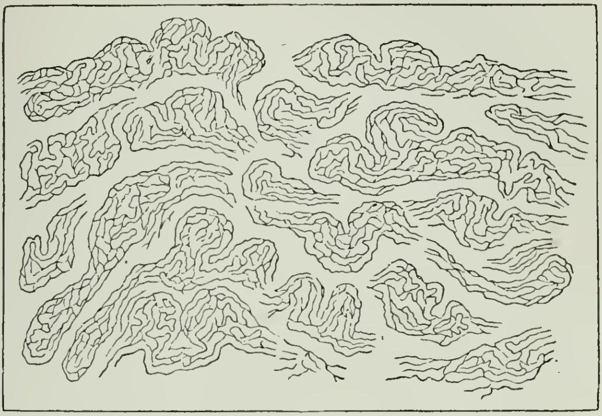
[1] Comptes Rendus, xxxi. 798, and L'Union Médicale, 1850. See, also, Dr. Donaldson, on M. Bernard's Discoveries in Amer. Journ. of the Med. Sciences, Oct. 1851, and H. Ludlow in Brit. and For. Med.-Chir. Rev., Jan. 1854, p. 65.

[2] Siebold and Kölliker's Zeitschrift, April, 1853.

[3] Lectures on the Physical Phenomena of Living Beings, by Dr. Pereira, Amer. edit., p. 110, Philad. 1848.

function exclusively to the lacteals; others sharing it between them and the veins. Let us inquire into the facts and arguments that have

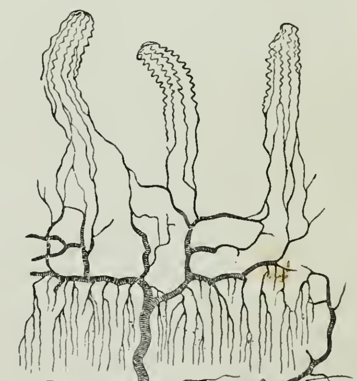
Fig. 67.



Capillary Plexus of the Villi of the Human Small Intestine, as seen on the Surface, after a successful injection, magnified 50 diameters.

been brought forward from time to time in support of these different opinions. The advocates for the exclusive agency of the chyliferous vessels affirm, *First*, That whatever is the vascular system, that effects the absorption of drinks, it must communicate freely with the cavity of the intestine; and that the chyliferous vessels do this. *Secondly*, That this system of vessels is the agent of chylous absorption:—a presumption, that it is likewise the agent of the absorption of drinks. *Thirdly*, That every physiologist, who has examined the chyle, has described its consistence to be in an inverse ratio with the quantity of drink taken; and, lastly, that when coloured and odorous substances have passed into the intestine, they have been found in the chyliferous vessels and not in the mesenteric veins. The experiments, adduced in favour of this last position are, however, so few and inadequate, that it is surprising they could have, for a time, so completely overturned the old theory. This effect was greatly aided by the zeal and ability of the Hunters, and of the Windmill Street School in

Fig. 68.



Vertical Section of the Coats of the Small Intestine of a Dog, showing only the commencing portions of the Portal Vein and the Capillaries. The injection has been thrown into the Portal Vein, but has not penetrated to the Arteries.

a. Vessels of the villi. *b.* Those of Lieberkühn's tubes. *c.* Those of the muscular coat.

general, who were the great improvers of our knowledge regarding the anatomy of the lymphatic system. John Hunter,[1]—who was one of the first that positively denied absorption by the veins, and maintained that of the lymphatics,—instituted the following ingenious and imposing experiment. He opened the abdomen of a living dog; laid hold of a portion of intestine, and pressed out the matters it contained with his hand. He then injected warm milk into it, which he retained by means of ligatures. The veins, belonging to the portion of intestine, were emptied of their blood by puncturing their trunks; and were prevented from receiving fresh blood, by the application of ligatures to the corresponding arteries. The intestine was returned into the cavity of the abdomen; and, in the course of half an hour, was again withdrawn and scrupulously examined; the veins were still found empty, whilst the chyliferous vessels were full of a white fluid. Mr. Hunter subsequently repeated the experiment with odorous and coloured substances, but without being able to detect them in the mesenteric veins. It may be remarked, also, that Musgrave,[2] Lister,[3] Blumenbach,[4] Seiler and Ficinus[5] assert, that they have detected substances, which had been thrown into the intestines of animals, in the chyle of the thoracic duct. The experiments of Hunter, however, are those, on which the supporters of this view of the question principally relied.

Physiologists, who believed in the absorption of liquids by the mesenteric veins, advanced similar arguments and much more numerous experiments. They affirmed that the mesenteric veins, like the chyliferous vessels, form constituent portions of the villi;—that if the chyliferous system is manifestly an absorbent apparatus, the same may be said of the venous system;—that if the chyle has appeared more fluid after much drink has been taken, the blood of the mesenteric veins was seen by Boerhaave to be more fluid under like circumstances; and, lastly, against the experiments of Hunter, numerous others were cited, showing clearly, that liquids, injected into the intestine, have been found in the mesenteric veins, whilst they could not be detected in the chyliferous vessels.

To the first experiment of Hunter it was objected;—that in his time the art of performing physiological experiments was imperfect; and that, in order to deduce useful inferences from it, we ought to know, whether the animal was fasting, or digestion was going on at the time it was opened; that the lymphatics ought to have been examined at the commencement of the experiment, to see whether they were full of chyle, or empty; as well as the milk, to notice whether it had experienced any change during its stay in the intestine; and lastly, that the reasons ought to have been assigned for the belief, that the lacteals were filled with milk at the end of the experiment, and not with chyle. Moreover, the experiment was repeated several times by MM. Flandrin and Magendie,[6]—careful and accurate observers,—yet, in no case, was the milk found in the chyliferous vessels. The

[1] Observations on certain parts of the Animal Economy, with notes by Richard Owen, F. R. S., Bell's Library edit., p. 307, Philad., 1840.

[2] Philosoph. Transact. for 1701, p. 996.

[3] Ibid., p. 819.

[4] Institut. Physiol., § 422.

[5] Journal Complément., xviii. 327.

[6] Précis, &c., edit. citat., ii. 201.

first experiment of Hunter could not, therefore, be looked upon as satisfactory. Some source of fallacy must have occurred, otherwise a repetition of the experiment should have been attended with like results, and we shall find, hereafter, that in another experiment, by that distinguished individual, a source of illusion existed, of which he was not aware, that was sufficient to account for the appearance he noticed.

The experiments of Hunter with odorous and coloured substances were repeated by many physiologists, and found even less conclusive than that with the milk. M. Flandrin, who was professor in the Veterinary School at Alfort, in France, thought that he could detect, in horses, an herbaceous odour of the blood of the mesenteric veins, but not of the chyle. He gave a horse a mixture of half a pound of honey, and the same quantity of asafœtida; and, whilst the smell of the latter was distinctly perceptible in the venous blood of the stomach and intestine, no trace of it existed in arterial blood and chyle. Sir Everard Home,[1] having administered tincture of rhubarb to an animal, around whose thoracic duct he had placed a ligature, found the rhubarb in the bile and urine. M. Magendie gave to dogs, whilst digesting, a quantity of alcohol diluted with water; and solutions of camphor, and other odorous fluids: on examining the chyle, half an hour afterwards, he could not detect any of those substances; but the blood of the mesenteric veins exhaled the odour, and afforded the substances by distillation. He gave to a dog four ounces of a decoction of rhubarb; and, to another, six ounces of a solution of prussiate of potassa in water. Half an hour afterwards, no trace of these substances could be detected in the fluid of the thoracic duct; whilst they could be in the urine. On another dog, he tied the thoracic duct, and gave it two ounces of a decoction of nux vomica. Death occurred as speedily as in an animal in which the thoracic duct was pervious. The result was the same, when the decoction was thrown into the rectum, where no proper chyliferous vessels exist. Having tied the pylorus in dogs, and conveyed fluids into their stomachs, absorption equally took place, and with the same results. Lastly, with M. Delille,[2] he performed the following experiment on a dog, which had eaten a considerable quantity of meat, in order that the chyliferous vessels might be easily perceived. An incision was made through the abdominal parietes; and a portion of the small intestine drawn out, on which two ligatures were applied at a short distance from each other. The lymphatics, which arose from this portion of the intestine, were very white, and apparent from the chyle that distended them. Two ligatures were placed around each of them; and they were divided between the ligatures. Every precaution was taken, that the portion of intestine drawn out of the abdomen should have no connexion with the rest of the body by lymphatics. Five mesenteric arteries and veins communicated with this portion of the intestine. Four of the arteries and as many veins were tied, and cut in the same manner as the lymphatics. The two extremities of the portion of intestine were now divided, and separated entirely from

[1] Lectures on Comparative Anatomy, i. 221, Lond., 1814.
[2] Précis, &c., ii. 203.

the rest. A portion, an inch and a half long, thus remained attached to the body by a mesenteric artery and vein only. These two vessels were separated from each other by a distance of four fingers' breadth; and the areolar coat was removed, to obviate the objection, that lymphatics might exist in it. Two ounces of a decoction of nux vomica were now injected into this portion of intestine, and a ligature was applied to prevent the exit of the injected liquid. The intestine, surrounded by fine linen, was replaced in the abdomen; and, in six minutes, the effects of the poison were manifested with their ordinary intensity:—every thing occurred as if the intestine had been in its natural condition. M. Ségalas[1] performed a similar experiment, leaving the intestine, however, communicating with the rest of the body by chyliferous vessels only. On injecting a solution of half a drachm of alcoholic extract of nux vomica into the intestine; the poisoning, which, in the experiment of M. Magendie, took effect in six minutes, had not occurred at the expiration of half an hour; but when one of the veins was untied and the circulation re-established, it supervened immediately. Westrumb[2] mixed rhubarb, turpentine, indigo, prussiate of potassa, and acetate of lead with the food of rabbits, sheep, and dogs. They were detected in the veins of the intestines and in the urine, but not in the chyle. The same facts were observed by Mayer[3] when rhubarb, saffron, and prussiate of potassa were introduced into the stomach. MM. Tiedemann and Gmelin likewise observed that the absorption of different colouring and odorous substances from the intestinal canal was effected exclusively by the veins. Indigo, madder, rhubarb, cochineal, litmus, alkanet, camboge, verdigris, musk, camphor, alcohol, spirits of turpentine, Dippel's animal oil, asafœtida, garlic, the salts of lead, mercury, iron, and baryta, were found in the venous blood, but never in the chyle. Prussiate of potassa and sulphate of potassa were the only substances, which, in their experiments, had entered the chyliferous vessels.

Such are the chief facts and considerations on which the believers in the chyliferous absorption and venous absorption of drinks rested their respective opinions. The strength was manifestly with the latter. Let it be borne in mind, that no sufficient experiments had been made, to encourage the idea, that any thing is contained in the chyliferous vessels except chyle; and that nearly all were in favour of absorption by the mesenteric veins. An exception to this, as regards the chyliferous and lymphatic vessels, seemed to exist in the case of certain salts. The prussiate and the sulphate of potassa—we have said—were detected in the thoracic duct by MM. Tiedemann and Gmelin; the sulphate of iron and the prussiate of potassa were found there by Messrs. Harlan, Lawrence, and Coates[4] of Philadelphia; and the last of these salts by Dr. Macneven, of New York. "I triturated," says Dr. Macneven,[5]

[1] Magendie's Journal de Physiologie, tom. ii.; and Précis, &c., ii. 208.

[2] De Phænomenis quæ ad Vias sic dictas Lotii clandestinas referuntur, Gotting., 1819.

[3] Meckel's Archiv., Band. iii.

[4] Philad. Journ. of Med. and Phys. Sciences, vol. ii.; and Harlan's Medical and Physical Researches, p. 458. Philad., 1835.

[5] New York Med. and Phys. Journ., June, 1822.

"one drachm of crystallized hydrocyanate of potassa with fresh butter and crumbs of bread, which being made into a bolus the same dog swallowed and retained. Between three and four hours afterwards, Dr. Anderson bled him largely from the jugular vein. A dose of hydrocyanic acid was then administered, of which he died without pain, and the abdomen was laid open. The lacteals and thoracic duct were seen well filled with milk-white chyle. On scratching the receptaculum, and pressing down on the duct, nearly half a teaspoonful of chyle was collected. Into this were let fall a couple of drops of the solution of permuriate of iron, and a deep blue was the immediate consequence." Professor J. Muller[1] placed a frog with its posterior extremities in a solution of prussiate of potassa, which reached nearly as high as the anus, and kept it so for two hours. He then carefully washed the animal, and having wiped the legs dry, tested the lymph taken from under the skin with a persalt of iron; it immediately assumed a bright blue colour, while that of the serum of the blood was scarcely affected by the test. In a second experiment, in which the frog was kept only one hour in the solution, the salt could not be detected in the lymph. These exceptions are strikingly corroborative of the rule. Of the various salts employed, only those mentioned appear to have been detected in the chyle of the thoracic duct. It is, therefore, legitimately presumable, that they entered adventitiously, and probably by simple endosmose—the mode in which venous absorption seems to be effected.

The property of endosmose possessed by animal tissues, has already been the subject of remark.[2] It was then shown, that they are not all equally penetrable; and that different fluids possess different penetrative powers. Such was proved to be the case in the experiments of MM. Tiedemann and Gmelin on the subject under discussion. Although various substances were placed in the same part of the intestinal canal, they were not all detected in the blood of the same vessels. Indigo and rhubarb were found in the blood of the vena porta. Camphor, musk, spirit of wine, spirit of turpentine, oil of Dippel, asafœtida, garlic, not in the blood of the intestines, but in that of the spleen and mesentery; prussiates of iron, lead, and potassa, in that of the veins of the mesentery; those of potassa, iron, and baryta, in that of the spleen; prussiate of potassa, and sulphates of potassa, iron, lead, and baryta, in that of the vena porta as well as in the urine; whilst madder and camboge were found in the latter fluid only.

Experiments by MM. Flandin and Danger[3] confirmed the general rule of the absorption of poisons from the digestive canal by the branches of the vena porta, and the diversity of locality in which they are met with. Their latest examinations were on the absorption of the salts of lead, which they detected in the digestive tube, liver, spleen, kidneys, and lungs, but not in the blood, heart, brain, muscles, or bones.

The evidence in favour of the action of the chyliferous vessels being restricted to the absorption of chyle, whilst the intestinal veins take up other matters, has not been, however, considered by some as conclusive as it is by us. M. Adelon,[4] for example, concludes, that, as

[1] Handbuch der Physiologie, u. s. w. Baly's translation, p. 279. Lond., 1838.
[2] Page 66.
[3] Gazette Médicale, 3 Févr., 1844.
[4] Physiologie de l'Homme, edit. cit., iii. 111.

the sectators, on both sides, employ absolutely the same arguments, we are compelled to admit, that the two vascular systems are under exactly similar conditions; and both, consequently, participate in the function. We have seen, that whatever may be the similarity of arguments, the facts are certainly not equal.[1] It is proper, however, to remark, that chemical analysts experience great difficulty in detecting inorganic substances when these are mixed with certain of the compounds of organization; and this may account for such substances not having been discovered in the thoracic duct, even when present there.

With regard to the mode in which the absorption of fluids is effected, a difference of opinion has existed, and chiefly as regards the question, —whether, as in the case of the chyle, any elaboration is effected, or whether the fluid, when it attains the interior of the vessel, is the same as without. The arguments in favour of these different views will be detailed under the head of Venous Absorption. We may merely observe, at present, that water,—the chief constituent of all drinks,—is an essential component of every circulating fluid;—that we have no evidence that any action of elaboration is exerted upon it: and that the ingenious and satisfactory experiments of Prof. J. K. Mitchell,[2] have shown, that it penetrates most, if not all, animal tissues better than any other liquid; and, consequently, passes through them to accumulate in any of its own solutions. It is probably in this way—that is, by imbibition,—that all venous absorptions are effected.

But it has been said:—if fluids pass so readily through the coats of the veins,—by reason of the extensive mucous surface, with which they come in contact, a large quantity of extraneous and heterogeneous fluid must enter the abdominal venous system when we drink freely, and the composition of the blood be consequently modified; and, if it should arrive, in this condition, at the heart, the most serious consequences might result. It has, indeed, been affirmed by a distinguished member of the profession[3] in this country, in a more ingenious than forcible argument to support a long-cherished—but now almost universally abandoned—hypothesis, that "it must at least be acknowledged, that no substance, in its active state, does reach the circulation, since it is shown, that a small portion even of the mildest fluid, as milk or mucilage, oil or pus, cannot be injected into the bloodvessels without occasioning the most fatal consequences." But the effects are here greatly dependent on the mode in which the injection is made. If a scruple of bile be sent forcibly into the crural vein, the animal generally perishes in a few moments. The same occurs, if a quantity of atmospheric air be rapidly introduced into a venous trunk. The animal, according to Sir Charles Bell,[4] dies in an instant, when a very little air is blown in:—and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame. In this way, according to Beauchêne, Larrey, Dupuytren, Warren of Boston, Mott and Stevens of New York, Delpech, and others, operations at

[1] Bostock's Physiol., 3d edit., p. 607. Lond., 1836.
[2] American Journal of the Medical Sciences, vii. 44, 58.
[3] Chapman, Elements of Therapeutics, 6th edit., p. 47, Philad., 1831.
[4] Animal Mechanics, P. ii. p. 42, London, 1829.

times prove fatal;—the air being drawn in by the divided veins. If, however, the scruple of bile, or the same quantity of atmospheric air be injected into one of the branches of the vena porta, no apparent inconvenience is sustained. M. Magendie[1] concludes, from this fact, that the bile and atmospheric air, in their passage through the myriads of small vessels into which the vena porta divides and subdivides in the substance of the liver, become thoroughly mixed with the blood, and thus arrive at the vital organs in a condition to be unproductive of mischief. This view is rendered the more probable by the fact, that if the same quantity of bile or of air be injected very slowly into the crural vein, no perceptible inconvenience is sustained. Dr. Blundell[2] injected in this manner five drachms into the femoral vein of a very small dog, with only temporary inconvenience; and, subsequently, three drachms of expired air, without much temporary disturbance; and M. Lepelletier[3] affirms, that in the amphitheatre of the *École Pratique* of Paris, in the presence of upwards of two hundred students, he injected thrice into the femoral vein of a dog, of middle size, at a minute's interval, three cubic inches of air, without observing any other effect than struggling, whining, and rapid movements of deglutition; and these phenomena existed only whilst the injection was going on. Since that he has often repeated the experiment with identical results,—"proving," he observes, "that the deadly action of the air is, in such case, mechanical, and it is possible to prevent the fatal effects by injecting it so gradually, that the blood has power to disseminate, and perhaps even to dissolve it with sufficient promptitude to prevent its accumulation in the cardiac cavities." From the experiments of Mr. Erichsen, however, the cause of death in such cases, would appear to be asphyxia.[4]

As liquids are frequently passed off by the urinary organs soon after they have been swallowed, it has been believed by some,—either that there are vessels which form a direct communication between the stomach and bladder; or that a transudation takes place through the parietes of the stomach and intestine, and that the fluids proceed through the intermediate areolar tissue to the bladder. Both these views, we shall hereafter show, are devoid of foundation.

In animals, in which the cutis vera is exposed, or the cuticle very thin, nutritive absorption is effected through that envelope. In the polypi, medusæ, radiaria, and vermes, absorption is active, and according to Zeder and Rudolphi,[5] entozoa, that live in the midst of animal humours, imbibe them through the skin. A few years ago, Jacobson[6] instituted experiments on the absorbing power of the helix of the vine (*Limaçon des vignes*). A solution of prussiate of potassa was poured over the body. This was rapidly absorbed, and entered the mass of blood in such quantity, that the animal acquired a deep blue colour when sulphate of iron was thrown upon it. In the frog, toad, sala-

[1] Précis Elémentaire, 2de édit., ii. 433. [2] Medico-Chirurg. Trans. for 1818, p. 65.
[3] Physiologie Médicale et Philosophique, i. 494, Paris, 1831.
[4] Bérard, Cours de Physiologie, iv. 94, Paris, 1855.
[5] Entozoorum Histor., i. 252, 275, Berlin, 1829.
[6] Mémoir. de l'Acad. des Sciences de Berlin, 1825, and Tiedemann, Traité Complet de Physiologie de l'Homme, edit. Fr., p. 242, Paris, 1831.

mander, &c., cutaneous absorption is so considerable, that occasionally the weight of water, taken in this way, is equal to that of the whole body. It will be seen hereafter, that the nutrition of the fœtus in utero is mainly, perhaps, accomplished by nutritive absorption effected through the cutaneous envelope.

II. ABSORPTION OF LYMPH OR LYMPHOSIS.

This function is effected by agents, that strongly resemble those concerned in the absorption of chyle. One part of the vascular apparatus is, indeed, common to both,—the *thoracic duct.* We are much less acquainted, however, with the physiology of lymphatic, than of chyliferous, absorption.

1. ANATOMY OF THE LYMPHATIC APPARATUS.

The lymphatic apparatus consists of lymphatic vessels, lymphatic glands or ganglia, and thoracic duct. The latter, however, does not form the medium of communication between all the lymphatic vessels and the venous system.

1. *Lymphatic vessels.*—These vessels exist in almost all parts of the body; and have the shape of cylindrical, transparent, membranous tubes, of small size, anastomosing freely with each other, so as to present, everywhere, a reticular arrangement. They are never, according to Professor Müller, so small as the arterial and venous capillaries, and are, almost without exception, visible to the naked eye. G. R. Treviranus asserts, that their walls, like the areolar membrane, and other tissues, are made up of minute elementary

Fig. 69.

Vessels and Lymphatic Glands of Axilla.

1. The axillary artery. 2. Axillary vein. 3. Brachial artery. 4. Brachial vein. 5. Primitive carotid artery. 6. Internal jugular vein. 7. Subcutaneous lymphatics of arm at its upper part. 8. Two or three of the most inferior and superficial glands into which the superficial lymphatics empty. 9. Deep-seated lymphatics which accompany brachial artery. 10. Lymphatics and glands which accompany infra-scapular bloodvessels. 11. Glands and lymphatics accompanying thoracica longa artery. 12. Deeper-seated lymphatics. 13. Axillary chain of glands. 14. Acromial branches of lymphatics. 15. Jugular lymphatics and glands. 16, 17. Lymphatics which empty into subclavian vein near its junction with right internal jugular vein.

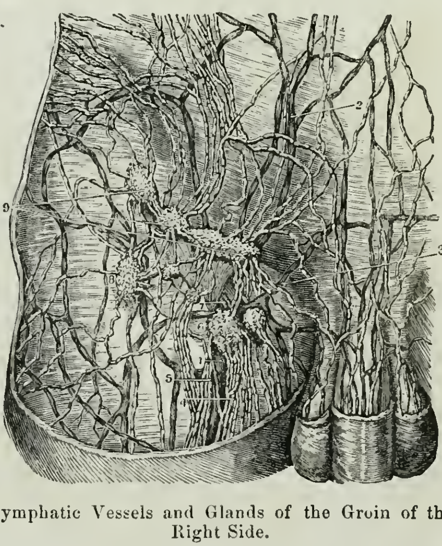
cylinders, of a diameter of from 0·001 to 0·006 millimètres, placed in a series, side by side and end to end, so as to constitute tubes which form networks, and open into larger lymphatic trunks. They are extremely numerous; more so, however, in some parts than others. They have not been found in the brain, spinal marrow, eye, or internal ear, bones, cartilages, or any non-vascular parts; but this is not a positive proof, that they do not exist in some of them. It may be, that they are so minute as to escape observation. In their progress towards the venous system, they go on forming fewer and fewer trunks; yet always remain small. This uniformity in size is peculiar to them. When an artery sends off a branch, its size is sensibly diminished; and when a vein receives a branch, it is enlarged; but when a lymphatic ramifies, there is generally little change of size, whether the branch given off be large or small.

The lymphatics consist of two planes,—the one *superficial*, the other *deep-seated*. The former creep under the outer covering of the organ, or of the skin, and accompany the subcutaneous veins. The latter are seated more deeply in the interstices of the muscles, or even in the tissue of parts; and accompany the nerves and great vessels. These planes anastomose with each other.

This arrangement occurs not only in the limbs, but the trunk, and in every viscus. In the trunk, the superficial plane is beneath the skin; and the deep-seated between the muscles and the serous membrane that lines the splanchnic cavities. In the viscera, one plane occupies the surface; the other appears to arise from the parenchyma.

The two great trunks of the lymphatic system, in which the lymphatic vessels of the various parts of the body terminate, are the thoracic duct, and the great lymphatic trunk of the right side. The course of the thoracic duct has been described already. It is formed of three great vessels;—one, in which all the lymphatics and lacteals of the intestines terminate; and the other two, formed by the union of the lymphatics of the lower half of the body. Occasionally, the duct consists of several trunks, which unite into one before reaching the subclavian vein; but more frequently it is double.

Fig. 70.



Lymphatic Vessels and Glands of the Groin of the Right Side.

1. Saphena magna vein. 2. Veins on the surface of abdomen. 3. External pudic vein. 4. Lymphatic vessels collected in fasciculi and accompanying the saphena vein on its inner side. 5. External trunks of the same set of vessels. 6. Lymphatic gland which receives all these vessels. It is placed on the termination of the saphena vein. 7. Efferent trunks from this gland; they become deep-seated and accompany the femoral artery. 8. One of the more external lymphatic glands of the groin. 9. A chain of four or five inguinal glands, which receive the lymphatics from the genitals, abdomen, and external portion of the thigh.

In addition to the lymphatics of the lower half of the body, the thoracic duct receives a great part of those of the thorax, and all those from the left half of the upper part of the body. At its termination in the subclavian, there is a valve so disposed as to allow the lymph to pass into the blood; and to prevent the reflux of the blood into the duct. We shall see, however, that its mode of termination in the venous system possesses other advantages. The great lymphatic trunk of the right side is formed by the absorbents from that side of the head and neck, and from the right arm. It is very short, being little more than an inch, and sometimes not a quarter of an inch, in length,—but of a diameter nearly as great as the thoracic duct. A valve also exists at the mouth of this trunk, which has a similar arrangement and office with that of the left side.

The lymphatics have been asserted to be more numerous than the veins; by some, indeed, the proportion has been estimated at fourteen superficial lymphatics to one superficial vein; whence it has been deduced, that the capacity of the lymphatic is greater than that of the venous system. This must be mere matter of conjecture. The same may be said of the speculations that have been indulged regarding the mode in which the lymphatic radicles arise,—whether by open mouths or by some spongy mediate body. The remarks made regarding the chylous radicles apply with equal force to the lymphatic.

It has been a matter of some interest to determine, whether the lymphatic vessels have other communications with the venous system than by the two trunks just described; or, whether, soon after their origin, they do not open into the neighbouring veins,—an opinion held by many of those, who believe in the doctrine of absorption by the lymphatics exclusively, to explain why absorbed matters are found in the veins. Several of the older, as well as more modern, anatomists, have professed this opinion; whilst it has been strenuously combated by Sömmering, Rudolphi,[1] and others. Vieussens affirmed, that, by means of injections, lymphatic vessels were distinctly seen originating from the minute arteries, and terminating in small veins. Sir William Blizard[2] asserts, that he twice observed lymphatics terminating directly in the iliac veins. Mr. Bracy Clarke[3] found, that the trunk of the lymphatic system of the horse had several openings into the lumbar veins. M. Ribes,[4] by injecting the supra-hepatic veins, saw the substance of the injection enter the superficial lymphatics of the liver. M. Alard[5] considers that the lymphatic and venous systems communicate at their origins. Vincent Fohmann[6] thinks, that the lymphatic vessels communicate directly with the veins, not only in the capillaries, but in the interior of the lymphatic glands. Lauth,[7] of Strasburg,—who went to Heidelberg to learn from Fohmann his plan of injecting,—announced the same facts in 1824. By this anatomical arrangement,

[1] Grundriss der Physiologie, u. s. w., 2ter Band, 2te Abtheilung, S. 247, Berlin, 1828.

[2] Physiological Observations on the Absorbent System of Vessels, Lond., 1787.

[3] Rees's Cyclopedia, art. Anatomy, Veterinary. [4] Magendie, Précis, etc., ii. 238.

[5] Du Siége et de la Nature des Maladies, ou Nouvelles Considérations touchant la Véritable Action du Système Absorbant, etc., Paris, 1821.

[6] Ueber die Verbindung der Saugadern mit den Venen, Heidelb., 1821; and Das Saugadersystem der Wirbelthiere, Heft 1, Heidelb., 1824; and Mém. sur les Communications des Vaisseaux Lymphatiques avec les Veines, Liége, 1832.

[7] Essai sur les Vaisseaux Lymphatiques, Strasbourg, 1824.

Lauth explains how an injection, sent into the arteries, reaches the lymphatics, without being effused into the areolar tissue; the injection passing from the arteries into the veins, and thence, by a retrograde route, into the lymphatics. M. Béclard believed, that this communication exists at least in the interior of the lymphatic glands; and he supported his opinion by the fact, that in birds, in which these glands are wanting, and are replaced by plexuses, the lymphatic vessels in the plexuses are distinctly seen opening into the veins. Lippi[1] has made these communications the subject of an express work. According to him, the most numerous exist between the lymphatic vessels of the abdomen, and the vena cava inferior and its branches. So numerous are they, that every vein receives a lymphatic vessel, and the sum of all would be sufficient to form several thoracic ducts. Opposite the second and third lumbar vertebræ, the lymphatic vessels are manifestly divided into two orders:—some ascending, and emptying themselves into the thoracic duct; others descending, and opening into the renal vessels and pelves of the kidneys. Lippi admits the same arrangement, as regards the chyliferous vessels; and he adopts it to explain the promptitude with which drinks are evacuated by the urine.

Subsequent researches have not, in general, confirmed the statements of Lippi. G. Rossi,[2] indeed, maintains, that the vessels, which Lippi took for lymphatics, were veins. It would appear, however, that when Rossi was in Paris, he was unable to demonstrate, when requested to do so by M. Breschet, the very things, that he had previously figured and described. Panizza, too, affirms, that no direct union or continuity between the venous capillaries and lymphatics has ever been made manifest to the eye, either in the human subject or the lower animals:[3] and, on the whole, the observations of Lippi as to the alleged termination of lymphatics in various veins of the abdomen have generally been either rejected as erroneous or held to refer to deviations from the normal condition.[4] It is proper to remark, however, that, recently, Dr. A. Nuhn,[5] Prosector at Heidelberg, has maintained, that there is a regular communication between the abdominal lymphatics and veins, and describes three cases of the kind which fell under his own observation. In two of these, the lymphatics opened into the renal veins; in the third into the vena cava. The article contains a good history of the views of different observers on the communication between the absorbents and veins.

We are perhaps justified in concluding with Panizza, that anatomy has not hitherto succeeded in determining, with physical certainty, in what relation the sanguiferous and lymphatic systems stand to each other, at their extreme ramifications.[6] M. Magendie[7] conceives the

[1] Illustrazioni Fisiologiche, etc., Firenz., 1825.

[2] Omodei's Annali Universali, Jan., 1826.

[3] Osservazioni Antropo-zootomico-fisiologiche, Pavia, 1833; and Breschet, Système Lymphatique, Paris, 1836.

[4] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Dr. Leidy, ii. 43, Philad., 1849.

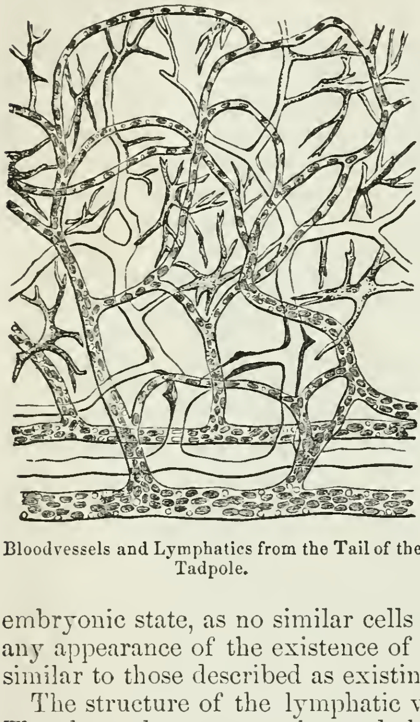
[5] Müller's Archiv. für Anatomie, u. s. w., Heft 2, S. 173, Berlin, 1848.

[6] See on both sides of this subject, Müller's Handbuch, u. s. w., Baly's translation, p. 273, Lond., 1838; and Weber's Hildebrandt's Handbuch der Anatomie, iii. 113, Braunschweig, 1831.

[7] Précis, &c., ii. 194.

most plausible view regarding the lymphatics to be:—that they arise by extremely fine roots in the substance of the membranes and areolar tissue, and in the parenchyma of organs, where they appear continuous with the final arterial ramifications;—as it frequently happens, that an injection sent into an artery passes into the lymphatics of the part to which it is distributed. By some, they are described as commencing either in closely meshed networks, interspersed among the bloodvessels of the several tissues, or else in pointed closed tubes or processes, as shown in the marginal figure of the lymph and bloodvessels in a part of the tail of the tadpole;—the bloodvessels being denoted by the corpuscles in them. In this state, many of the extremities of the lymphatics appear to communicate with pointed or star-shaped cells; but this, according to Messrs. Kirkes and Paget,[1] may be peculiar to the embryonic state, as no similar cells are seen in the adult; nor is there any appearance of the existence of cells for the elaboration of lymph, similar to those described as existing in the intestinal villi.

Fig. 71.



Bloodvessels and Lymphatics from the Tail of the Tadpole.

The structure of the lymphatic vessels is like that of the lacteals. They have the same number and character of coats; the same crescentic valves or sphincters, occurring in pairs, and giving them the knotted and irregular appearance, for which they are remarkable;—every contraction indicating the presence of a pair of valves, or sphincter. The minutest lymphatics seem, however, to be destitute of valves: but they are discernible in those of less than one-third of a line in diameter, and have the same structure as those of the veins. In man, each lymphatic, before reaching the venous system, passes through a *lymphatic gland* or *ganglion*, formerly called a *conglobate gland.* These organs are extremely numerous; and in shape, structure, and probably in function, resemble entirely the mesenteric glands. (See page 217.) They, therefore, do not demand distinct notice. They exist more particularly in the axillæ, neck, neighbourhood of the lower jaw, beneath the skin of the nape of the neck, and in the groins, and pelvis in the neighbourhood of the great vessels. The connection between the lymphatics and those glands is the same as that between the chyliferous vessels and mesenteric glands.

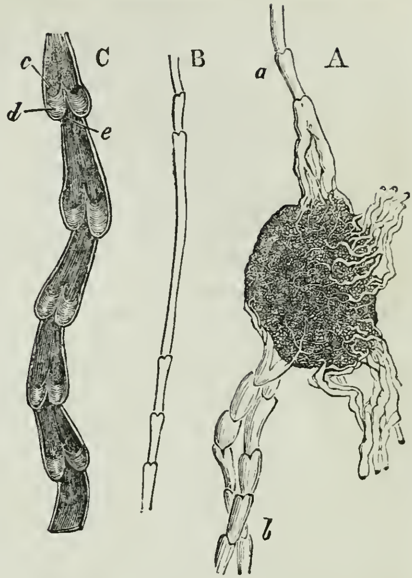
M. Chaussier includes in the lymphatic system certain organs, whose uses in the economy are not manifest,—the thymus gland, the thyroid,

[1] Manual of Physiology, 2d Amer. edit., p. 209, Philad., 1853.

the supra-renal capsules, and perhaps the spleen. These he considers to be varieties of the same species, and terms them all *glandiform ganglions.*

The *thymus gland* is a body consisting of distinct lobes, situate at the upper and anterior part of the thorax behind the sternum. It has been considered to belong more particularly to fœtal existence, and will be investigated hereafter.

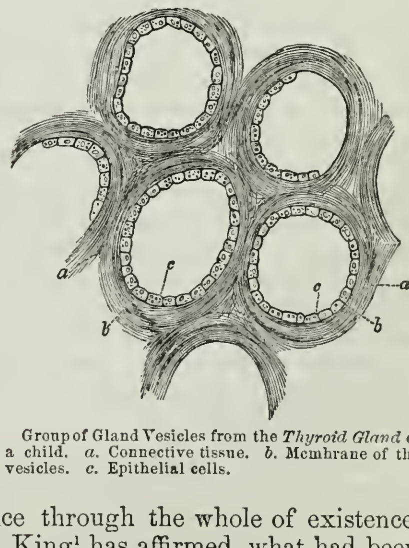
Fig. 72.



A. One of the inguinal lymphatic glands injected with mercury. *a.* Afferent lymphatic vessel from the lower extremity. *b.* Efferent vessel. Others are also seen.
B. One of the superficial lymphatic trunks of the thigh.
C. One of the femoral lymphatic trunks laid open longitudinally to display the valves within it. *c.* Sinus between the valve and the wall of the vessel. *d.* Surface of one valve, directed towards the opposite. *e.* Semicircular attached margin of the valve.

The *thyroid gland* or *body*, is, also, a lobated organ, situate at the anterior part of the neck beneath the skin and subcutaneous muscles, and resting on the anterior and inferior part of the larynx, and first rings of the trachea. It is formed of lobes, which subdivide into lobules and granula; is of a red, and at times yellow colour; and presents, internally, cells or vesicles, filled with a viscid and colourless or yellowish fluid, which, collected on the point of a knife after incising the gland, appears like a weak solution of gum, and is almost devoid of the ropiness of white of egg. Put into common rectified spirit, it seems to lose only a little water; becomes solid, but not opaque; and loses but little. The same effects result in the cells when the gland is boiled for a quarter of an hour: no apparent solution occurs. The thyroid gland has no excretory duct; and, consequently, it is difficult to imagine its use. It is larger in the fœtus than in the adult, and has been supposed to be, in some way, inservient to fœtal existence. It continues, however, through life; receives large arteries, as well as a number of nerves and lymphatics, and hence, it has been supposed, fills some important office through the whole of existence. This, however, is conjectural. Mr. King[1] has affirmed, what had been

Fig. 73.



Group of Gland Vesicles from the *Thyroid Gland* of a child. *a.* Connective tissue. *b.* Membrane of the vesicles. *c.* Epithelial cells.

[1] Guy's Hospital Reports, i. 437, Lond., 1836, and Sir Astley Cooper., ibid., p. 448.

already imagined by many, that the absorbent vessels of the thyroid convey its peculiar secretion to the great veins of the body. It is the seat of *goitre* or *bronchocele*, the *swelled neck*, *Derbyshire neck*, *papas*, &c., as it has been termed in different quarters of the globe,—a singular affection, which is common at the base of lofty mountains in all parts of the world; and for the cure of which, we have a valuable remedy in iodine. The eutrophic agency of this drug is particularly exerted on the thyroid, and it affords an additional instance, to the many already known, of remedial agents exerting their properties upon a particular organ, without our being able, in the slightest degree, to account for the preference. Iodine stimulates, perhaps, the absorbent vessels of the gland to augmented action; it certainly modifies the nutrition of the organ; and the consequence is absorption of the morbid deposit.

The *supra-renal* or *atrabiliary capsules* or *glands* are small bodies in the abdomen, behind the peritoneum, and above each kidney, which are larger in the fœtus than in the adult. The arteries distributed to them are of considerable size. They are lobular and granular, and like the kidneys, according to Kölliker, consist of a so-called *cortical*, and a *medullary* portion, the former being principally formed of a stroma of connective tissue, in which are oval spaces filled with a granular substance, mixed with nuclei, or even cells. The medullary portion also consists of a stroma of connective tissue formed of laminæ, which are prolonged from the cortical connective tissue, in the network of which lies a pale, fine, granular substance, containing pale cells, and a few fat or pigment granules, the cells frequently having distinct nucleoli, "with large nucleoli."[1] Sir Everard Home[2] described their interior as filled with a viscid fluid pulp or oil, which is reddish in the fœtus, yellow in childhood, and brown in old age. Under the microscope, the pulp has been found to consist of minute oil-like spheroids, of very unequal size, varying from $\frac{1}{24000}$th to $\frac{1}{6000}$th of an inch in diameter.[3] They continue during life; but with their precise uses we are unacquainted. By the ancients, they were believed to be the secretory organs of the imaginary atrabilis; hence their name. Sir Everard Home considers that they act like a filter, "by which any oil left in the arterial branches that are near the kidneys may be separated, and prevented from making its escape by the tubæ uriniferæ of these glands." Dr. Carpenter[4] thought the only function that can be assigned them with anything like probability, is that of serving as a means of conveying into the veins the blood sent through the renal artery, when, from any cause, the secreting function of the kidneys is partly or wholly checked, and their capillary circulation stagnates in consequence.

All these bodies are probably concerned in hæmatosis; but at the same time—as shown hereafter,—they may act under special circumstances as diverticula to the blood and hence merit the name—now generally assigned to them—of *vascular glands*. Their functions are treated of elsewhere.

[1] Mikroskopische Anatomie, 2ter Band, s. 377, Leipz., 1854, and Amer. edit. of the Sydenham Society's edit. of his Manual of Histology, by Dr. Da Costa, p. 615, Philadelphia, 1854.

[2] Lect. on Comp. Anat., v. 262, Lond., 1828.

[3] Gulliver, in Gerber's General Anatomy, p. 103.

[4] Principles of Human Physiology, § 710, Lond., 1842.

2. LYMPH.

Lymph may be procured in two ways, either by opening a lymphatic vessel, and collecting the fluid that issues from it,—but this is an uncertain method,—or by making an animal fast four or five days, and obtaining the fluid from the thoracic duct. This has been considered pure lymph; but it must be mixed with the product of the digestion of the different secretions from the portion of the digestive tube above the origin of the chyliferous vessels. Chyle itself is nothing more than lymph of the intestines, containing matter absorbed from the digested food; and in the intervals of digestion lymph alone is found in the chyliferous vessels.

The fluid, obtained as above-mentioned, is of a rosy, slightly opaline tint; a markedly spermatic odour, and saline taste. At times, it is of a decidedly yellowish colour; at others, of a madder red; circumstances which may have given occasion to erroneous inferences from experiments made on the absorption of colouring matters. Its specific gravity has been found, by some, to be 1022·28: by others, 1·037. Its colour is affirmed to be more rosy in proportion to the length of time the animal has fasted. When examined by the microscope, it exhibits globules or corpuscles like those of the chyle; and, like the chyle, bears considerable analogy, in its chemical composition, to the blood. Both may, indeed, without impropriety, be regarded as rudimental blood.

Bodies similar to these *lymph corpuscles* are seen mingled with the blood, occupying generally the space between the main current and the parietes of the vessel. Some, however, regard them as blood corpuscles in process of solution or disintegration; and M. Mandl[1] thinks they do not exist in the fluid during life, but are owing to the coagulation of its fibrin. More recently, he has stated, that from experiments made with M. Breschet, it was evidently impracticable to procure pure lymph by opening the lymphatic hearts of frogs. Blood globules always existed in it; and this, he thinks, throws doubts on the view, that lymph corpuscles are transformed into blood corpuscles.

When left at rest, lymph separates into two portions;—the one a liquid, nearly like the serum of the blood; the other a coagulum or clot of a deeper rosy hue; in which is a multitude of reddish filaments, disposed in an arborescent manner; and, in appearance, very analogous to the vessels distributed in the tissue of organs. When a portion of coagulated lymph is examined, it seems to consist of two parts:—the one solid, formed of numerous cells, which contains the other or more liquid part; and if the former be separated, the latter coagulates. Mr. Brande[2] collected the lymph from the thoracic duct of an animal, that had been kept without food for twenty-four hours. He found its chief constituent to be water, besides which, it contained chloride of sodium and albumen:—the latter being in such minute quantity, that it coagulated only by the action of galvanism. The lymph of a dog yielded to M. Chevreul, water, 926·4; fibrin, 4·2; albumen, 61·0; chloride of sodium, 6·1; carbonate of soda, 1·8; phosphate of lime, phosphate of magnesia, and carbonate of lime, 0·5.

[1] Anatom. Microscop., i. 15.

[2] Turner's Chemistry, 4th Amer. edit., p. 567.

That of the horse yielded to M. Lassaigne, water, 192·5; fibrin, 0·33; albumen, 5·73; chlorides of sodium and potassium, with soda and phosphate of lime, 1·43. Total, 100. MM. Marchand and Colberg[1] found its constituents to be,—water, 96·926; fibrin, 0·520; albumen, 0·434; osmazome (and loss), 0·312; fatty oil and crystalline fat, 0·264; chloride of sodium, chloride of potassium, carbonate and lactate of an alkali, and sulphate of lime, phosphate of lime, and oxide of iron, 1·544. Total, 100·000. Gmelin found, in 1000 parts of human lymph, water, 961·0; solid constituents, 30·74; fibrin, 5·20; albumen, 4·34; extractive matter, 3·12; fluid and crystalline fat, 2·64; chlorides of sodium and potassium, alkaline sulphates and carbonates, sulphate and phosphate of lime, and peroxide of iron, 15·44. M. L'Héritier[2] analyzed the lymph obtained from the thoracic duct of a man who died from softening of the brain, and took nothing but a little water for thirty hours preceding his death. It contained in 1000 parts,—water, 924·36; fibrin, 3·20; fat, 5·10; albumen, 60·02; salts, 8·25. Lymph, collected from the absorbent vessels of the neck of a horse, was elaborately analyzed by Nasse, and found to contain in 1000 parts,—water, 950; solid residue, 50; albumen with fibrin, 39·111; water extract, 3·248; spirit extract, 0·877; alcohol extract, 0·755; ethereal extract, 0·088; oleate of soda, 0·575; carbonate of soda, 0·560; phosphate of soda, 0·120; sulphate of potassa, 0·233; chloride of sodium, 4·123; carbonate of lime, 0.104; phosphate of lime with some iron, 0·095; carbonate of magnesia, 0·044; silica, 0·067. He compared the lymph with the serum from the blood of a healthy horse; and found a remarkable coincidence in the salts of the two fluids.

	Serum.	Lymph.
Alkaline chlorides	4·055	4.123
Alkaline carbonates (oleate of soda included) . .	1·130	1·135
Alkaline sulphates	0·311	0·233
Alkaline phosphates	0·115	0·120
	5·611	5·611[3]

The same observer[4] has given a tabular view of six analyses of the lymph of the horse and ass.

	Reuss and Emmert.	Gmelin. I.	Gmelin. II.	Lassaigne.	Rees.	Nasse.
Water	960·0	961·0	967·70	925·00	965·36	950·00
Fibrin . . . nearly	3·0	2·5	1·30	3·30	1·20 }	39.11
Albumen		27·5	14·85		12·00 }	
Extractive matter soluble only in water		2·1	2·58	57.36	13.19	3·25
Extractive matter soluble in alcohol	39·6	6·9	9·69		2·40	1·63
Fat		0·0	traces		a trace	0·09
Soluble salts, Salts of lime, magnesia and silica } contained in the extractive matters				14·34	5·85	5·61
and silica					a trace }	0.31
Oxide of iron						
Loss	0·4		3.88			

[1] Müller's Archiv. Jahrgang, 1838, s. 129, cited in V. Bruns, Lehrbuch der Allgemeinen Anatomie, s. 135, Braunschweig, 1841.

[2] Traité de Chimie Pathologique, p. 18, Paris, 1842.

[3] Simon's Animal Chemistry, Sydenham Soc. edit., p. 353, Lond., 1845, or Amer. edit., Philad., 1846.

[4] Wagner's Handwörterbuch der Physiologie, 9te Lieferung, s. 396, Braunschweig, 1845.

A comparative analysis of the chyle and lymph of the ass has been made by Dr. G. O. Rees.[1] The fluids were obtained from the chyliferous and lymphatic vessels seven hours after a full meal, previous to their entrance into the thoracic duct.

	Chyle.	Lymph.
Water	90·237	96·536
Albuminous matter	3·516	1·200
Fibrinous matter	0·370	0.120
Animal extractive matter, soluble in water and alcohol	0·332	0·240
Animal extractive matter, soluble in water only	1·233	1·319
Fatty matter	3·601	a trace.
Salts:—alkaline chloride, sulphate, and carbonate, with traces of alkaline phosphate and oxide of iron	0·711	0.585
	100·000	100·000

The chyle—it will be observed—contains a larger proportion of decidedly organizable matters. Dr. Rees[2] examined the contents of the thoracic duct of a human subject, procured an hour and a quarter after death by hanging. They amounted to six drachms, and yielded the following results:—

Water	90·48
Albumen, with traces of fibrinous matter	7.08
Aqueous extractive (zomodine)	0·56
Alcoholic extractive (osmazome)	0·52
Alkaline chloride, carbonate, and sulphate, with traces of phosphate, and oxide of iron	0·44
Fatty matters	0·92
	100·00

Messrs. Gubler and Quévenne[3] had an opportunity of examining human lymph obtained from a varicose dilatation of the superficial lymphatic network of the skin, and found it to consist of—

Fibrin	0·056	6·013
Fatty matter	0·382	
Caseiform matter, containing only one per cent. of earthy phosphate with traces of iron	4·275	
Hydro-alcoholic extract, containing sugar, and leaving, by incineration, 0·730 of a saline mixture, composed of chloride of sodium, and phosphate and carbonate of soda	1·300	
Water	93·987	

Chyle and lymph strikingly, therefore, resemble each other; and according to M. Millon,[4] when taken from the same animal at one time, the analogy in composition is very great. Without impropriety they may, indeed, be termed rudimental blood.[5]

It is impossible to estimate the quantity of lymph contained in the body. It would seem, that notwithstanding the great capacity of the lymphatic vessels, there is, under ordinary circumstances, little fluid circulating in them. Frequently, when examined, they have appeared

[1] Lond. Med. Gazette, Jan., 1841.

[2] Proceedings of the Royal Society, Feb. 10, 1842.

[3] Comptes Rendus des Seances et Mémoires de la Société de Biologie, Année 1854, p. 50, Paris, 1855.

[4] Archives Générales de Médecine, Févr., 1850, p. 237.

[5] See, on the whole subject of the lymph, Lehmann, Lehrbuch der Physiologischen Chemie, ii. 290, Leipz., 1850, and Amer. edit. of Dr. Day's translation, by Dr. Robt. E. Rogers, ii. 31, Philad., 1855.

to be empty, or pervaded by a mere thread of lymph. M. Magendie[1] endeavoured to obtain the whole of the lymph from a dog of large stature. He could collect but an ounce and a half; and it appeared to him that the quantity increased whenever the animal was kept fasting; but on this point he does not seem to express himself positively. On the other hand, M. Collard de Martigny[2] obtained nine grains of lymph, in ten minutes, from the thoracic duct of a rabbit which had taken no food for twenty-four hours; and Geiger, from three to five pounds of lymph daily, from the foot of a horse from which the same quantity had been flowing several years, without injury to the health. The estimate made by Bidder has been referred to elsewhere. (Page 220).

3. PHYSIOLOGY OF LYMPHOSIS.

The term *lymphosis* has been proposed by Chaussier for the action of elaboration by which lymph is formed,—as *chylosis* has been used for the formation of chyle, and *hæmatosis* for that of the blood. In describing the organs concerned, the striking similarity—we might almost say—identity in structure and arrangement between them and the chyliferous organs will have been apparent. A part of the vascular apparatus is common to both; and they manifestly constitute one and the same system. This would be sufficient to induce us to assign them similar functions; and it would require powerful and positive testimony to establish an opposite view. At one period, lymph was considered to be simply the watery portion of the blood; and the lymphatic vessels were regarded as the continuation of ultimate arterial ramifications. It was affirmed, that the blood, on reaching the terminal branches of the arteries, separated into two parts; the red and thicker portion returning to the heart by the veins; and the white, serous portion—*liquor sanguinis*—by the lymphatics.[3] The reasons for this belief were, the great resemblance between lymph and the serum of the blood; and the facility with which an injection passes, in the dead body, from the arterial into the lymphatic capillary vessels. M. Magendie has revived the ancient doctrine; and, of consequence, no longer considers the lymphatics to form part of the absorbent system; but to belong to the circulatory apparatus, and to serve the office of waste pipes, in case of emergency. Without canvassing this subject now, we may assume it for granted, that the lymph which circulates in the lymphatic vessels is as identical in its nature, or as little subject to alteration, as the chyle; and that, consequently, whatever may be the materials, besides the liquor sanguinis, that constitute it, an action of elaboration and selection must be exerted in its formation.

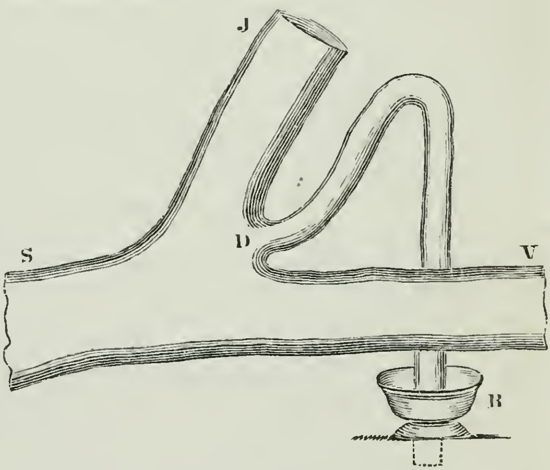
It has been conceived, that many of the tissues of the body, the serous membranes, for example, do not receive red blood; and must, consequently, be nourished by white blood. The lymphatics, in such cases, have been considered to be to the white arteries what the veins are to the red. Such has been presumed to be one of their offices, but it will be seen, hereafter, that all the tissues supplied with vessels receive red blood; and hence it is unnecessary to suppose, that the lymphatics execute any venous function.

[1] Op. citat., ii. 192.
[2] Journal de Physiologie, viii. 266.
[3] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 210, Philad., 1853.

Assuming, for the present, that lymph is wholly obtained from materials already deposited in the body; the next inquiry is,—the mode in which its formation and simultaneous absorption are effected. On this topic, we have no arguments to employ in addition to those adduced regarding the function of the chyliferous radicles. In every respect, they are situate identically, and to the history of the latter we must refer for an exposition of the little we know of this part of lymphosis.

The causes of the progression of the lymph in the vessels are the same as those that influence the chyle. In addition, however, to those mentioned under *chyliferous absorption*, there is one that applies equally to the chyliferous and lymphatic vessels: this is the mode in which the thoracic duct enters the subclavian vein. It has been already observed that it occurs at the point of junction between the jugular and subclavian, as at D, Fig. 74, where J represents the jugular, and V S the subclavian, in which the blood flows from V towards S, the cardiac extremity.

Fig. 74.



Termination of Thoracic Duct.

Now, it is a physical fact, that when a small tube is inserted perpendicularly into the lower side of a horizontal conical pipe, in which water is flowing from the narrower to the wider portion; and if the small vertical tube be made to dip into a vessel of water, not only will the water of the larger pipe not descend into the vessel; but it will draw up the water through the small tube so as to empty the vessel.[1] Instead of supposing the canals, in Fig. 74, to be veins and the thoracic duct; let us presume that they are rigid mechanical tubes; and that the extremity of the tube D, which represents the thoracic duct, dips into the vessel B. As the fluid, proceeding from J to S and V to S, is passing from the narrower portions of conical tubes to wider, it follows, that the fluid will be drawn out of the vessel B, simply by traction, or, by what Venturi[2] terms the *lateral communication of fluids*. This would happen in whatever part of the vessel the tube B D terminated. But its insertion at D has another advantage. By the mode in which the current from J towards S unites with that from V towards S, a certain degree of diminished pressure must

[1] Sir C. Bell, in Animal Mechanics, p. 41, Library of Useful Knowledge, Lond., 1829.
[2] Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798.

exist at D; so that the atmospheric pressure, on the surface of the water in the vessel B, will be exerted in propelling it forwards. In the progress, then, of the chyle and lymph along the thoracic duct, not only may the traction of the more forcible stream along the veins draw the fluid in the thoracic duct along with it, but, owing to the diminished pressure at the mouth of the duct, atmospheric pressure may have some—although probably but little—influence, in forcing the chyle and lymph from the chyliferous and lymphatic radicles onwards. The lymphatic glands have been looked upon as small hearts for the propulsion of lymph; and Malpighi accounts for the greater number in the groin in this way;—the lymph having to ascend to the thoracic duct against gravity: and this appears to have been somewhat the opinion of Bichat. There seems, however, to be nothing in their structure that ought to lead to this belief; and, if it be not muscular or contractile, it is manifest, that their number must have the effect of retarding rather than accelerating the flow. The most prevalent sentiment is, that they are somehow concerned in the elaboration of the lymph; but their exact functions we know nothing definite. What has been already said of the mesenteric ganglions, and of their probable agency in the formation of chyle corpuscles is equally applicable to them and their agency in the formation of lymph corpuscles.

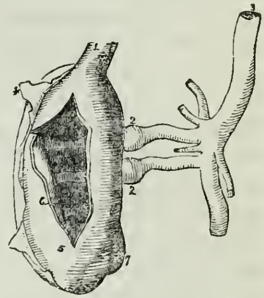
On the subject of the moving powers of the lymph, M. Adelon[1] has remarked, that if we admit it to be the serous portion of the blood; and that the lymphatics are vessels of return, as the veins are, the heart might be considered to have the same influence over lymphatic, that it has been presumed to have over venous, circulation; and whether we admit this or not, as the thoracic duct opens into the subclavian vein, the influence of the suction power of the organ on the venous blood may affect the progression of the chyle also. It cannot, however, as Müller[2] remarks, be the primary cause of the motion of the chyle, for Autenrieth, Tiedemann, and Carus observed, when a ligature was applied to the thoracic duct, that the part of the duct below the ligature became distended even to bursting. We shall see hereafter, that during inspiration, absorption, it is imagined, may be facilitated by the dilatation of the chest, and the necessary diminution of pressure on the heart and great vessels.

Professor Müller[3] discovered, that the frog, and several other amphibious animals, are provided with large receptacles for lymph, situate immediately under the skin, and, like the heart, exhibiting distinct and regular pulsations. The use of these lymph hearts appears to be to propel the lymph along the lymphatics. In the frog, four of them have been found; two posterior, behind the joint of the hip; and two anterior, on each side of the transverse process of the third vertebra, and under the posterior extremity of the scapula. The pulsations of these lymphatic hearts do not correspond with those of the sanguiferous heart; nor do those of the right and left sides occur synchronously.

[1] Art. Absorption, in Dict. de Médecine, 2de édit., i. 239, Paris, 1832; and Physiologie de l'Homme, edit. cit. iii. 92.
[2] Handbuch, u. s. w.; and Baly's translation, p. 284, Lond., 1838.
[3] Philos. Transact. for 1833; and op. cit. See, also, his Observations on the Lymphatic Hearts of Tortoises, in Müller's Archiv., Heft 1, 1840.

They often alternate irregularly. Prof. E. H. Weber has described them in a larger species of serpent—*python bivittatus*;[1] and Dr. Joseph J. Allison, of Philadelphia,[2] a young and zealous observer, who was cut off early in his career, saw them in the tadpole, the frog, the sauria, ophidia, and chelonia. His researches led him to conclude:—*First.* That the pulsations of the lymphatic organs vary in different specimens (frogs and tadpoles) from 60 or less to 200 per minute. *Secondly.* That they vary in the same individual so as sometimes to become double in frequency. *Thirdly.* That the lymphatic pulsations bear no fixed relation to those of the pulmonary heart or to respiration, the lymphatic hearts beating—on an average—with greater frequency.

Fig. 75.



Lymph Heart of Python Bivittatus, Heart 9 lines long; 4 broad.

4. External areolar coat. 5. Thick muscular coat; four muscular columns cross the cavity, which communicates with three lymphatics—only one, 1, seen here, and two veins, 2, 2. 6. Smooth lining membrane of the cavity. 7. An appendix or auricle, the cavity of which communicates with the other.

Professor Stannius[3] has discovered lymphatic hearts in various birds.

Unlike that of the heart, the action of these lymph hearts appears to be dependent upon a certain limited portion of the spinal cord; for Volkmann[4] found, that by dividing the anterior or motor roots of the spinal nerves connected with them, the pulsations immediately ceased.

The course of the lymph is by no means rapid. If a lymphatic be divided on a living individual, the lymph oozes slowly, and never with a jet. Mr. Cruikshank estimated its velocity along the vessels to be four inches per second or twenty feet per minute; but it is probably much less. M. Collard de Martigny[5] obtained nine grains of lymph in ten minutes from the thoracic duct of a rabbit, which had taken no food for twenty-four hours. Having pressed out the lymph from the principal lymphatic trunk of the neck, in a dog, the vessel filled again in seven minutes: in a second experiment it filled in eight minutes. The data for any correct evaluation of this matter are altogether inadequate, the deranging influence of all such experiments being considerable.

In man and living animals, the lymphatics of the limbs, head, and neck rarely contain lymph; their inner surface appearing to be merely lubricated by a very thin fluid. Occasionally, however, the lymph stops in different parts of the vessels; distends them; and gives them an appearance very like that of varicose veins, except as to colour. Sömmering states, that he saw several in this condition on the top of the foot of a female; and M. Magendie one around the corona glandis of a male. In dogs, cats, and other living animals, lymphatics, filled with lymph, are frequently seen at the surface of the liver, gall-bladder, vena cava, vena porta, and at the sides of the spine. Magendie remarks,

[1] Müller, op. citat., p. 275.
[2] American Journal of the Medical Sciences, for August, 1838.
[3] Müller's Archiv., 1843, Heft 5.
[4] Ibid., 419, Berlin, 1844; and Valentin, Lehrbuch der Physiologie des Menschen, ii. 769, Braunschweig, 1844.
[5] Journal de Physiologie, tom. viii.

that he has never met with the thoracic duct empty, even when the lymphatics of the rest of the body were entirely so.[1] It must be recollected, however, that the thoracic duct must always contain the product of the digestion either of food or of secretions from the alimentary tube. The stagnation of lymph in particular vessels has given occasion to the belief, that it flows with different degrees of velocity in different parts of the system; and this notion has entered into the pathological views of writers, who have presumed, that something like determinations of lymph may occur, and produce lymphatic swellings. M. Bordeu,[2] indeed, speaks of *currents* of lymph. All the phenomena of the course of the lymph negative, however, this presumption; and induce us to believe, that its progress is pretty uniform, and always slow; and when an accumulation, or engorgement, or stagnation occurs in any vessel, it is more probably owing to increased formation by the lymphatic radicles that communicate with the vessel in question, or to loss of tone in the parietes of the engorged lymphatics.

The lymph, which proceeds by the thoracic duct, is emptied, along with the chyle, into the subclavian vein. At the confluence, a valve is placed, which does not, however, appear to be essential, as the duct opens so favourably between the two currents from the jugular and subclavian, that there is little or no tendency in the blood to reflow into it. It has been suggested, that its use may be, to moderate the instillation of the fluid from the thoracic duct into the venous blood.

With regard to the question, whether the lymph is the same at the radicles of the lymphatics as in the thoracic duct, or whether it does not gradually become more and more animalized in its course towards the venous system, and especially in its progress through the lymphatic glands, the remarks made upon this subject, as respects the chyle, apply with equal force to the lymph.

The glands of the mesentery, and lymphatics in general, seem to be concerned in some of the most serious diseases. Swelling of the lymphatic glands of the groin may indicate the existence of a venereal sore on the penis. A wound on the foot produces tumefaction of the inguinal glands; one on the hand inflames those of the axilla. Whenever, indeed, a lymphatic gland is symptomatically enlarged, the source of irritation will be found at a greater distance from the vein into which the great lymphatic trunks pour their fluid than the gland is. In plague, one of the essential phenomena is swelling of the lymphatic glands of the groin and axilla; hence, it has been termed *adeno-adynamic fever* (from αδην, a gland). In scrofula, the lymphatic system is generally deranged; and, in the doctrine of Broussais, a very active sympathy is affirmed to exist between the glands of the mesentery, and the mucous surface of the stomach and intestines. This discovery, we are told, belongs to the "*physiological doctrine*," which has shown, that all gastro-enterites are accompanied by tumefaction of the mesenteric glands: although chyle may be loaded with acrid, irritating, or even poisonous matters, it traverses the glands with impunity, provided it does not inflame the gastro-enteric mucous surface. "Our attention," Broussais[3]

[1] Précis, &c., ii. 224.

[2] Œuvres Complètes, par Richerand, Paris, 1818.

[3] Traité de Physiologie, &c., and Bell and La Roche's translation, 3d Amer. edit., p. 362, Philadelphia, 1832.

adds, "has been for a long time directed to this question, and we have not observed any instance of mesenteric ganglionitis, which had not been preceded by well-evidenced gastro-enteritis." The discovery will not immortalize the "doctrine." We should as naturally look for tumefaction of the mesenteric glands or ganglia, in cases of irritation of the intestine, as for enlargement of the glands of the groin in irritation of the foot.

Lastly; the lymph, from whatever source obtained—united with the chyle—is discharged into the venous system. Both, therefore, go to the composition of the body. They are entirely analogous in properties; but differ materially in quantity;—the nutritious fluid, formed from materials obtained from without, being far more copious. A due supply of it is required for continued existenee; yet the body can live for a time, when the supply of nutriment is entirely cut off. Under such circumstances, the necessary proportion of nutritive fluid must be obtained from the decomposition of the tissues; but, from the perpetual drain, that takes place through the various excretions, this soon becomes insufficient, and death is the result. In a note to a recent edition of his "Principles of Human Physiology,"[1] Dr. Carpenter remarks, that at the time of the publication of the first edition of his work (1842) he was under the impression, that the view maintained by him, "that the special function of the lymphatics like that of the lacteals is *nutritive* absorption," was altogether novel. The author attaches little value to originality in such matters; but he thinks it well to state, that the doctrine in the text is that adopted by him in the first edition of this work (1832), and taught by him ever since he has been a teacher; yet he is far from regarding it as original with him.

We have seen, then, that both chyle and lymph are poured into the venous blood;—itself a compound of the residue of arterial blood, and various heterogeneous absorptions. As an additional preliminary to the investigation of the agents of internal absorption, let us inquire into the nature and course of the fluid contained in the veins; but so far only as to enable us to understand the function of absorption; the other considerations relating to the blood appertain to the function of circulation.

III. VENOUS ABSORPTION.

The apparatus of venous absorption consists of myriads of vessels called *veins*, which commence in the very tissues, by what are called *capillary vessels*, and thence pass to the great central organ of the circulation—the *heart;* receiving, in their course, the products of the various absorptions effected not only by themselves, but by the chyliferous and lymphatic vessels. The anatomy of the venous system will be given under Circulation.

[1] Fourth American edition, p. 506, Philad., 1850. See on this subject, Adelon, Art. Absorption, in Dict. de Médecine, i. 117, Paris, 1821; and Moultrie, American Journal of the Medical Sciences for 1827, and On the Organic Functions of Animals, Charleston, 1844.

1. PHYSIOLOGY OF VENOUS ABSORPTION.

Whilst the opinion prevailed universally, that the lymphatics are the sole agents of absorption, the fluid, circulating in the veins, was considered to consist entirely of the residue of arterial blood, after it had passed through the capillary system, and been subjected to the different nutritive processes. We have seen, however, that drinks are absorbed by the mesenteric veins; and we shall hereafter find, that various other substances enter the venous system. It is obvious, therefore, that venous blood cannot be simply the residue of arterial blood; and we can thus account for the greater capacity of the venous than of the arterial system. The facts, which were referred to, when considering the absorption of fluids from the intestinal canal, may have been sufficient to show, that veins are capable of absorbing; as odorous and colouring properties of substances were distinctly found in the mesenteric veins. A question arises, whether any selection or elaboration is exerted, as in the case of the chyle, or whether the fluid, when it attains the interior of the vessel, is the same as without? M. Adelon,[1]—who, with many of the German physiologists, believes in both venous and lymphatic absorption, and venous and chyliferous absorption,—conceives, that a vital action takes place at the very extremities of the venous radicles, precisely similar to that which is presumed to be exerted at the extremities of the lymphatic and chyliferous radicles. In his view, consequently, an action of elaboration is exerted upon the fluid, which becomes, in all cases, converted into venous blood at the very moment of absorption. On the other hand, MM. Magendie,[2] Fodéra,[3] and others maintain, that the substance when possessed of the necessary tenuity soaks through the vessel; and that this act of imbibition is purely physical. In their view, consequently, the fluid within the vessel must be the same as without.

In favour of the vital action of the veins we have none of that evidence, which strikes us in the case of the chyliferous and lymphatic vessels. In the last we invariably find fluids, identical—in all essential respects—in physical characters; and never containing extraneous matter,—if we make abstraction of certain salts, that have been occasionally met with in the thoracic duct. In the veins, on the other hand, the sensible properties of odorous and colouring substances have been frequently apparent. It may be argued, however, that the fluid, flowing in the veins, is as identical in composition as the chyle or the lymph. This is true; but it must be recollected, that the greater part of it is the residue of arterial blood; and that its hue and other sensible properties are such as to disguise any absorbed fluid, not itself possessing strong characteristics. The fact,—now indisputable,—that various substances, placed outside the veins, have been detected in the blood within, is not only a proof that the veins absorb; but that no action of elaboration is exerted on the absorbed fluid. Of this we have the most convincing proof in certain experiments by

[1] Art. Absorption, in Dict. de Médecine, 2de édit., i. 239, Paris, 1832; and Physiologie de l'Homme, 2de édit., iii. 113, Paris, 1829.
[2] Précis, &c., 2de édit., ii. 271.
[3] Recherches Expérimentales sur l'Exhalation et l'Absorption, Paris, 1823.

M. Magendie.[1] In exhibiting to his class the mode in which medicines act upon the system, he showed, on a living animal, the effects of introducing a quantity of water, of the temperature of 104° Fah., into the veins. In performing this experiment, it occurred to him to notice what would be the effect produced by artificial plethora on the phenomena of absorption. Having injected nearly a quart of water into the veins of a dog of middle size, he placed in the cavity of the pleura a small dose of a substance with the effects of which he was familiar, and was struck with the fact, that they did not exhibit themselves for several minutes after the ordinary period. He immediately repeated the experiment, and with a like result. In several other experiments, the effects appeared at the ordinary time, but were manifestly feebler than they ought to have been from the dose of the substance employed; and were kept up much longer than usual.

In another experiment, having introduced as much water as the animal could bear without perishing,—which was about two quarts,—the effects did not occur at all. After having waited nearly half an hour for their developement, which generally required only about two minutes, he inferred, that if the distension of the bloodvessels was the cause of the defect of absorption, if the distension were removed, absorption ought to take place. He immediately bled the animal largely in the jugular; and, to his great satisfaction, found the effects manifesting themselves as the blood flowed. He next tried whether, if the quantity of blood were diminished at the commencement of the experiment, absorption would be more rapid; and the result was as he anticipated. An animal was bled to the extent of about half a pound; and the effects, which did not ordinarily occur until after the second minute, appeared before the thirtieth second. As the results of these experiments seemed to show, that absorption is in an inverse ratio to the degree of vascular distension, he inferred, that it is effected physically; is dependent upon capillary attraction; and ought to take place as well after death as during life. To prove this, he instituted the following experiments.—He took a portion of the external jugular of a dog, about an inch long and devoid of branches. Removing carefully the surrounding areolar tissue, he attached to each extremity a glass tube, by means of which he kept up a current of warm water within it. He then placed the vein in a slightly acid liquor, and carefully collected the fluid of the current. During the first few minutes, it exhibited no change; but, in five or six minutes, became sensibly acid. This experiment was repeated on veins taken from the human subject with like results; and not only on veins but on arteries.

Similar experiments were next made on living animals. He took a young dog, about six weeks old, whose vessels were thin, and, consequently, better adapted for the success of the experiment, and exposed one of its jugular veins. From this he dissected entirely the surrounding matter, and especially the areolar tissue, with the minute vessels that ramified upon it, and placed it upon a card, in order that there might be no point of contact between it and the surrounding parts. He then let fall upon its surface, and opposite the middle of the card, a thick

[1] Op. citat., ii. 273.

watery solution of nux vomica,—a substance, that exerts a powerful action on dogs. He took care, that no particle of the poison touched any thing but the vein and card; and that the course of the blood, within the vessel, was free. Before the expiration of three minutes, the effects he expected appeared,—at first feebly, but afterwards with so much activity, that to prevent fatal results he had to inflate the lungs. The experiment was repeated on an older animal with the same results; except that, as might have been expected, they were longer in exhibiting themselves, owing to the greater thickness of the parietes of the veins.

Satisfied, as regarded the veins, he now directed his attention to the arteries:—the results were the same. They were, however, slower in appearing than in the case of the veins, owing to the tissue of the arteries being less spongy. It required upwards of a quarter of an hour for imbibition to be accomplished. In one of the rabbits, which died under the experiment, they had an opportunity of discovering, that absorption could not have been effected by any small veins, that had escaped dissection. One of the carotids,—the subject-vessel of the experiment,—was taken from the body; and the small quantity of blood, adherent to its inner surface, was found by M. Magendie, and his friends who assisted at the experiment, to possess the extreme bitterness that characterizes nux vomica. These experiments were sufficient to prove the fact of imbibition by the large vessels, both in the dead and in the living state. His attention was now directed to the smaller; which seemed, *à priori*, favourable to the action, from their delicacy of organization. He took the heart of a dog, that had died the day before, and injected water, of the temperature of 86° of Fah., into one of the coronary arteries, which readily returned by the coronary vein into the right auricle, whence it was allowed to flow into a vessel. Half an ounce of water, slightly acidulated, was now placed in the pericardium. At first, the injected fluid did not exhibit any signs of acidity; but, in five or six minutes, the evidences were unequivocal.

From these facts, M. Magendie[1] draws the too broad deduction, that "all bloodvessels, arterial and venous, dead or living, large or small, possess a physical property capable of accounting for the principal phenomena of absorption." We shall endeavour to show, that it explains only certain varieties of absorption,—those in which the vessel receives the fluid unmodified,—but that it is unable to account for other absorptions in which an action of selection and elaboration is necessary.

After these experiments were performed, others were instituted by MM. Ségalas[2] and Fodéra,[3] from which the latter physiologist attempts to show, that exhalation is simply a *transudation* of substances from the interior of vessels to the exterior; and absorption an *imbibition* or passage of fluids from the exterior to the interior. The facts adduced by M. Fodéra in support of his views will be considered under the head of SECRETION. They go chiefly to show the facility with which sub-

[1] Précis, &c., ii. 283. [2] Magendie's Journal de Physiol., ii. 217.

[3] Recherches Expériment. sur l'Absorption, &c., Paris, 1824, and Magendie's Journal, &c., iii. 35.

stances penetrate the parietes of vessels and other tissues of the body; an action which he found to be singularly accelerated by the galvanic influence. Prussiate of potassa was injected into the cavity of the pleura; and sulphate of iron introduced into that of the peritoneum in a living animal. Under ordinary circumstances, it requires five or six minutes before the two substances meet by imbibition through the diaphragm; but the admixture is instantaneous if the diaphragm be subjected to a slight galvanic current. The same fact is observed, if one of the liquids be placed in the urinary bladder, and the other in the abdomen; or the one in the lung, and the other in the cavity of the pleura. It was further found, that, according to the direction of the current, the union took place in the one or the other cavity. Dr. Bostock,[1] in commenting on these cases, thinks it must be admitted, that they "go very far to prove that membranes, *perhaps even during life*, and certainly after death, before their texture is visibly altered, have the power of permitting the transudation of certain fluids." That such imbibition occurs during life is indisputably proved. If the clear and decisive experiments of Magendie and Fodéra had been insufficient to establish it, the additional testimony,—afforded by Lawrence, Coates, and Harlan; by Dutrochet, Faust, Mitchell, Rogers, Draper, and others, —would be ample.

By the different rates of penetrativeness of different fluids, and of permeability of different tissues, we can explain why imbibition may occur in one set of vessels and not in another; and the constant current, established in the interior of the vessel is a sufficient reply to the suggestion, that there may not be the same tendency to transude after the fluid has entered it. M. Adelon[2] is of opinion, that under the view of imbibition we ought to find substances in the arteries and lymphatics also; but a sufficient objection to this would be,—the comparative tardiness, with which the former admit the action; and the selection, and, consequently, refusal, exerted by the latter; but even here evidences of adventitious imbibition are occasionally met with; as in the case of salts, which—we have seen—have been detected in the thoracic duct, after having been introduced into the cavity of the abdomen.

The two following experiments by Prof. J. K. Mitchell,[3] which are analogous to numerous others, performed in the investigation of this subject, well exhibit endosmose in living tissues. A quantity of a solution of acetate of lead was thrown into the peritoneal cavity of a young cat; sulphuretted hydrogen being passed, at the same time, into the rectum. In four minutes, the poisonous gas killed the animal. Instantly on its death, the peritoneal coat of the intestines, and the parietes of the cavity in contact with them, were found lined with a metallic precipitate, which adhered to the surface, and was removable by nitric acid moderately diluted. It was the characteristic precipitate of sulphuretted hydrogen, when acting on lead. In another experiment on a cat, a solution of acetate of lead was placed in the thorax, and sulphuretted hydrogen in the abdomen. Almost immediately after the entrance of the sulphuretted hydrogen into the abdominal cavity, death ensued.

[1] Physiology, edit. cit., p. 629. [2] Op. cit.
[3] American Journal of the Medical Sciences, vii. 44, Philada., 1830.

On inspecting the thoracic side of the diaphragm, which was done as quickly as possible, the tendinous part of it exhibited the leaden appearance of the precipitate thrown down by sulphuretted hydrogen. The experiment of J. Müller, referred to in a preceding page, establishes the same fact.

It may be concluded, then, that all living tissues imbibe liquid matters which come in contact with them; and that the same occurs to solids, provided they are soluble in the humours, and especially in the serum of the blood. But although imbibition is doubtless effected by living tissues, too great a disposition has been manifested to refer all the vital phenomena of absorption and exhalation to it. Even dead animal membrane exerts a positive agency in respect to bodies placed on either side of it. In the early part of this work[1] the phenomena of imbibition were investigated, and it was there explained how endosmose and exosmose are affected through organic membranes. A careful examination of those phenomena would lead to the belief, that in many cases the membrane exerts no agency except in the manner last suggested by M. Dutrochet. This is signally manifested in experiments with porous, inorganic substances; and it has been ingeniously and ably confirmed by Dr. Draper,[2] of New York, who found, that the phenomena were elicited, when, instead of an organic tissue, fissured glass was employed. Still, as has been demonstrated, the nature of the septum or membrane has in other cases a marked effect on endosmose.

Sir David Barry,[3]—in different memoirs laid before the *Académie Royale de Médecine*, the *Académie Royale des Sciences* of Paris, and the *Medico-Chirurgical Society* of London,—maintained, that the whole function of external absorption is a physical result of atmospheric pressure; and "that the circulation in the absorbing vessels and in the great veins depends upon this same cause in all animals possessing the power of contracting and dilating a cavity around that point to which the centripetal current of their circulation is directed." In other words, it is his opinion, that, at the time of inspiration, a tendency to a vacuum is produced in the chest by its expansion; and as the atmospheric pressure externally thus ceases to be counterbalanced, the pressure without occasions the flow of blood towards the heart along the veins. The consideration of the forces that propel the blood will afford us an opportunity of saying a few words on this view; at present, we may only observe, that Sir David ascribes absorption,—which he explicitly states to be, in his opinion, extra vital,—to the same cause. In proof of this, he instituted numerous experiments, in which the absorption of poisons from wounds appeared to take place, or to be suspended, according as the wounds were, as he conceived, exposed to atmospheric pressure, or freed from its influence by the application of a cupping-glass. The same quantity of poison, which, under ordinary circumstances, destroyed an animal in a few seconds, was rendered completely innocuous by the exhausted glass; and what is singular, even when the symptoms had commenced, the application of the cupping-glass

[1] See p. 66.

[2] Amer. Journ. of the Med. Sciences, for Aug. 1836, p. 276; Nov., 1837, p. 122; May, 1838, p. 23, and August, 1838—more especially the last two.

[3] Experimental Researches on the Influence of Atmospheric Pressure upon the Circulation, &c., Lond. 1826.

had the effect of speedily and completely removing them; a fact of essential importance in its therapeutical relations. In commenting on the conclusions of Sir D. Barry, Messrs. Addison and Morgan,[1]—who maintain the doctrine, that all poisonous agents produce their specific effects upon the brain, and general system, through the sentient extremities of nerves, and through the sentient extremities of nerves only; and that, when such agents are introduced into the current of the circulation in any way, their effects result from the impression made upon the sensible structure of the bloodvessels, and not from their direct application to the brain itself,—contend, that the soft parts of the body, when covered by an exhausted cupping-glass, must necessarily, from the pressure of the edges of the glass, be deprived for a time of all connexion, both nervous and vascular, with the surrounding parts;—that the nerves must be partially or altogether paralysed by compression of their trunks; and that, from the same cause, all circulation through the veins and arteries within the area of the glass must cease; that the rarefaction of the air within the glass being still farther increased by means of the small pump attached to it, the fluids, in the divided extremities of the vessels, are forced into the vacuum, and, with these fluids, either a part or the whole of the poison, which had been introduced; and that, in such a condition of parts, the compression, on the one hand, and the removal of the poison from the wound on the other, will sufficiently explain the result of the experiment, either according to the views of those who conceive the impression to be made on the nerves of the bloodvessels, or of those who think, that the agent must be carried along with the fluid of the circulation to the part to be impressed.

Thus far allusion has been made only to the passage of tenuous fluids into the veins. It has been already seen, that many albuminous and saccharine solutions after having been exposed to the gastric and intestinal juices pass into the radicles of the portal veins to be conveyed to the liver to undergo assimilation.

Insoluble substances, too, have been detected by Professor Oesterlen[2] in the mesenteric veins. On administering levigated charcoal to animals for five or six days in succession, the blood of these veins exhibited distinctly particles of charcoal of different sizes, some of them so large, that it was a matter of surprise how they could have made their way into the blood through the mucous membrane and the walls of the bloodvessels. We have no difficulty, consequently, in comprehending how the mild chloride and other insoluble preparations of mercury might be able to enter the bloodvessels in this manner.

The observations of Oesterlen have been confirmed by Mensonides and Donders[3] not only with charcoal, but with sulphur, and with starch, which is readily detected in the blood by the iodine test. The latter is inclined to think that they enter the lacteals rather than the veins, as he finds them deposited in the lungs more than the liver. It is difficult to conceive how they effect their passage. The extreme velocity of the blood in the vessels may exert a degree of traction on them

[1] An Essay on the Operation of Poisonous Agents upon the Living Body, Lond., 1829.

[2] Heller's Archiv., Bd. iv. Heft 1, cited in Lond. Med. Gazette for July, 1847.

[3] Canstatt's Jahresbericht, 1851, p. 122, Würzburg, 1852; and Henle und Pfeufer's Zeitschrift, 1851, Bd. i. s. 415–27.

which may account for their entrance, when it could not be effected through dead membrane.

Such would seem to be the main facts regarding the absorbent action of the veins, which rests on as strong evidence as we possess regarding any of the functions of the body; yet, in the treatise on Animal and Vegetable Physiology by Dr. Roget,[1] we find it passed by without a comment!

We have still to inquire into the agents of internal and adventitious absorption.

IV. INTERNAL ABSORPTION.

On this point but few remarks will be necessary, after the exposition of the different vascular actions concerned in absorption. The term comprehends *interstitial absorption*, and the *absorption of recrementitial fluids*. The *first* comprises the agency by which the different textures of the body are decomposed and conveyed into the mass of blood. It will be considered more at length under the head of NUTRITION; the *second*, that of the various fluids effused into cavities; and the *third*, that which is effected on the excretions in their reservoirs or excretory ducts. All these must be accomplished by one of the two sets of vessels previously described; lymphatics, or veins, or both. Now, we have attempted to show, that an action of selection and elaboration is exerted by lymphatics; whilst we have no evidence of such action in the case of the veins. It would follow, then, that all the varieties of internal absorption, in which the substance, when received into the vessel, possesses different characters from those it had when without, must be executed by lymphatics; whilst those, in which no conversion occurs, take place by the veins. In the constant absorption, and corresponding deposition, incessantly going on in the body, the solid parts must be reduced to their elements, and a new compound be formed; inasmuch as we never find bone, muscle, cartilage, membrane, &c., existing in these states in any of the absorbed fluids; and it is probable, therefore, that, at the radicles of the lymphatic vessels, they are converted into the same fluid—the lymph—in like manner as the heterogeneous substances in the intestinal canal afford to the lacteals the elements of a fluid the character of which is always identical. On the other hand, when the recrementitial fluid consists simply of the serum of the blood, more or less diluted, there can be no obstacle to the passage of its aqueous portion immediately through the coats of the veins by imbibition, whilst the more solid part is taken up by the lymphatic vessels. In the case of excrementitious fluids, there is reason to believe, that absorption simply removes some of their aqueous portions; and this, it is obvious, can be effected directly by the veins, through imbibition. The facts, connected with the absorption of substances from the interior of the intestine, have clearly shown, that the chyliferous vessels alone absorb chyle, and that the drinks and adventitious substances pass into the mesenteric veins. These apply, however, to *external* absorption only; but similar experiments and arguments have been brought forward by the supporters of the two opinions, in regard to substances

[1] Bridgewater Treatise, Lond., 1834; Amer. edit., Philad., 1836.

placed on the peritoneal surface of the intestine, and other parts of the body. Whilst some affirm, that they have entered the lymphatics; others have only been able to discover them in the veins. Mr. Hunter, having injected water coloured with indigo into the peritoneal cavity of animals, saw the lymphatics, a short time afterwards, filled with a liquid of a blue colour. In animals, that had died of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and peritoneum filled with blood; and he asserts, that, having kept his feet for some hours in water, swelling of the inguinal glands supervened, with transudation of a fluid through the gland; coryza, &c. M. Desgenettes observed the lymphatics of the liver containing a bitter, and those of the kidneys a urinous, lymph. Sömmering detected bile in the lymphatics of the liver; and milk in those of the axilla. M. Dupuytren relates a case, which M. Magendie conceives to be much more favourable to the doctrine of absorption by the lymphatic vessels than any of the others. A female, who had an enormous fluctuating tumour at the upper and inner part of the thigh, died at the Hôtel Dieu, of Paris, in 1810. A few days before her death, inflammation occurred in the subcutaneous areolar tissue at the inner part of the tumour. The day after dissolution, M. Dupuytren opened the body. On dividing the integuments, he noticed white points on the lips of the incision. Surprised at the appearance, he carefully dissected away some of the skin, and observed the subcutaneous areolar tissue overrun by whitish lines, some of which were as large as a crow's quill. These were evidently lymphatics filled with puriform matter. The glands of the groin, with which these lymphatics communicated, were injected with the same matter. The lymphatics were full of the fluid, as far as the lumbar glands; but neither the glands nor the thoracic duct presented any trace of it.[1] On the other hand, multiplied experiments have been instituted, by throwing coloured and odorous substances into the great cavities of the body; and these have been found always in the veins, and never in the lymphatics.

To the experiments of Mr. Hunter, objections have been urged, similar to those brought against his experiments to prove the absorption of milk by the lacteals; and sources of fallacy have been pointed out. The blue colour, which the lymphatics seemed to him to possess, and which was ascribed to the absorption of indigo, was noticed in the experiments of Messrs. Harlan, Lawrence, and Coates;[2] but they discovered that this was an optical illusion. What they saw was the faint blue, which transparent substances assume, when placed over dark cavities. Mr. Mayo[3] has also affirmed that the chyliferous lymphatics always assume a bluish tint a short time after death, even when the animal has not taken indigo. The cases of purulent matter, &c., found in the lymphatics, may be accounted for by the morbid action having produced disorganization of the vessel, so that the fluid could enter the lymphatics directly; and, if once within, its progression could be readily understood.

M. Magendie[4] asserts, that M. Dupuytren and he performed more

[1] Magendie, Précis, &c., 2de édit., ii. 195, et seq.; and Adelon, art. Absorption, Dict. de Méd., 2de édit., i. 239, and Physiologie de l'Homme, 2de édit., iii. 65, Paris, 1829.
[2] Harlan's Physical Researches, p. 459, Philad., 1835.
[3] Outlines of Human Physiology, 3d edit., Lond., 1833. [4] Op. cit., ii. 211.

than one hundred and fifty experiments, in which they submitted to the absorbent action of serous membranes different fluids, and never found any of them within the lymphatic vessels. These fluids produced their effects more promptly, in proportion to the rapidity with which they were capable of being absorbed. Opium exerted its narcotic influence; wine produced intoxication, &c., and M. Magendie found, from numerous experiments, that the ligature of the thoracic duct in no respect diminished the promptitude with which these effects supervened. The partisans of lymphatic absorption, however, affirm that even if these substances are met with in the veins, it by no means follows, that absorption has been effected by them; for the lymphatics, they assert, have frequent communications with the veins; and, consequently, they may still absorb and convey their products into the venous system. In reply to this, it may be urged, that all the vessels —arterial, venous, and lymphatic—appear to have intercommunication; but there is no reason to believe, that the distinct offices, performed by them, are, under ordinary circumstances, interfered with; and, again, where would be the necessity for these intermediate lymphatic vessels, seeing that imbibition is so readily effected by the veins? The axiom—*quod fieri potest per pauca, non debet fieri per multa*—is here strikingly appropriate. The lymphatics, too, as we have endeavoured to show, exert an action of selection and elaboration on substances exposed to them; but, in the case of venous absorption, there is not the slightest evidence, that any such selection exists,—odorous and coloured substances retaining, within the vessel, the properties they had without. Lastly. Where would be the use of organs of a distinct lymphatic circulation opening into the thoracic duct, seeing that the absorbed matters might enter the various venous trunks directly through these supposititious communicating lymphatics; and ought we not occasionally to be able to detect in the lymphatic trunks some evidence of those substances, which their fellows are supposed to take up and convey into the veins? These carrier lymphatics have obviously been devised to support the tottering fabric of exclusive lymphatic absorption,—undermined, as it has been, by the powerful facts and reasonings that have been adduced in favour of absorption by veins.

From the whole of the preceding history of absorption, we are of opinion, that the chyliferous and lymphatic vessels form only chyle and lymph, refusing all other substances, with the exception of saline and other matters, that enter probably by imbibition,—that the veins admit every liquid, which possesses the necessary tenuity; and that whilst all the absorptions, which require the substances acted upon to be decomposed and transformed, are effected by chyliferous and lymphatic vessels; they that are sufficiently thin, and demand no alteration, are accomplished directly through the coats of the veins by imbibition; and we shall see that such is the case with several of the transudations or exhalations.

V. ACCIDENTAL ABSORPTION.

The experiments, to which reference has been made, have shown, that many substances, adventitiously introduced into various cavities, or placed in contact with different tissues, have been rapidly absorbed into the blood, without experiencing any transformation. Within certain limits, the external envelope of the body admits of this function; but by no means to the same extent as its prolongation, which lines the different excretory ducts. The absorption of drinks is sufficient evidence of the activity of the function as regards the gastro-enteric mucous membrane. The same may be said of the pulmonary mucous membrane. Through it, oxygen and nitrogen pass to reach the blood in the lungs, as well as carbonic acid in its way outwards. Aromatic substances, such as spirit of turpentine, breathed for a time, are detected in the urine; proving that their aroma has been absorbed; and it is by absorption, that contagious miasmata probably produce their pestiferous agency. Dr. Madden,[1] however, thinks that the lungs do not absorb watery vapour with the rapidity, or to the extent, that has been imagined; whilst Dr. A. Combe[2] hazards the hypothesis, that owing apparently to the extensive absorption of aqueous vapour by the lungs, the inhabitants of marshy and humid districts, as the Dutch, are remarkable for the predominance of the lymphatic system.

Not only do the tissues, as we have seen, suffer imbibition by fluids, but by gases also: the experiments of Chaussier and Mitchell astonish us by the rapidity and singularity of the passage of the latter through the various tissues;—the rapidity varying according to the permeability of the tissue, and the penetrative power of the gas.

a. *Cutaneous Absorption.*

On the subject of *cutaneous absorption*, much difference of sentiment has prevailed;—some asserting it to be possible to such an extent, that life may be preserved, for a time, by nourishing baths. It has also been repeatedly affirmed, that rain has calmed the thirst of shipwrecked mariners who have been, for some time, deprived of water. It is obvious, from what we know of absorption, that, in the first of these cases, the water only could be absorbed; and even the possibility of this has been denied by many. Under ordinary circumstances, it can happen to a trifling extent only, if at all; but, in extraordinary cases, where the system has been long devoid of its usual supplies of moisture, and where we have reason to believe, that the energy of absorption is increased, such imbibition may be possible. Sanctorius,[3] Von Gorter,[4] Keill,[5] Mascagni,[6] Madden,[7] R. L. Young,[8] Dill,[9] and others believe, that this kind of absorption is not only frequent but easy. It has been affirmed, that after bathing the weight of the body has been manifestly augmented; and the last of these individuals has adduced many facts and arguments to support the position. Strong testimony has been brought forward in favour of extensive absorption of moist-

[1] Experimental Inquiry into the Physiology of Cutaneous Absorption, p. 64, Edinb., 1838.

[2] Principles of Physiology applied to the Preservation of Health, 5th edit., p. 72, Edin., 1836.

[3] De Static. Medic., Lugd. Bat., 1711.

[4] De Perspirat. Insensib., Lugd. Bat., 1736.

[5] Tentamin. Medico-Physic., Lond., 1718.

[6] Vas. Lymphat. Hist., Senis, 1783.

[7] Op. cit., p. 58.

[8] De Cutis Inhalatione, Edinb., 1813.

[9] Edinb. Medico-Chir. Transact., ii. 350.

ure from the atmosphere. This is probably effected rather through the pulmonary mucous surface than the skin. A case of ovarian dropsy is referred to by Dr. Madden,[1] in which the patient, during eighteen days, drank 692 ounces of fluid; and discharged by urine and paracentesis 1298 ounces, being an excess of 606 ounces of fluid egesta over the fluid ingesta. Bishop Watson, in his Chemical Essays, states, that a lad at Newmarket, having been almost starved, in order that he might be reduced to the proper weight for riding a match, was weighed at 9, and again at 10, A. M., when he was found to have gained nearly 30 ounces in weight in the interval, although he had only taken half a glass of wine. Dr. Carpenter[2] gives a parallel case, which was related to him by Sir G. Hill, Governor of St. Vincent. A jockey had been for some time in training for a race in which Sir G. Hill was much interested, and had been reduced to the proper weight. On the morning of the race, suffering much from thirst, he took one cup of tea, and shortly afterwards his weight was found to have increased six pounds, so that he was incapacitated for riding. These cases certainly appear difficult of belief: yet the authority is good. Dr. Carpenter presumes, that nearly the whole of the increase in Bishop Watson's case, and at least three-fourths of it in Sir G. Hill's case, must be attributed to cutaneous absorption, which was probably stimulated by the wine that was taken in the one, and by the tea in the other. Bichat was under the impression, that, in this way he imbibed the tainted air of the dissecting room, in which he passed a large portion of his time. To avoid an objection, that might be urged against this idea,—that the miasmata might have been absorbed by the air-passages, he so contrived his experiment, as by means of a long tube, to breathe the fresh outer air; when he found, that the evidence, which consisted in the alvine evacuations having the smell of the miasmata of the dissecting-room, continued. It is obvious, however, that such an experiment would hardly admit of satisfactory execution, and it is even doubtful, whether there was any actual relation between the assigned effect and the cause. The testimony of MM. Andral, Boyer, Duméril, Dupuytren, Serres, Lallemand, Ribes, Lawrence, Parent-Duchatelet, and that afforded by the author's own observation, are by no means favourable to the great unwholesomeness of cadaveric exhalations.[3]

Dr. J. Bradner Stuart[4] found, after bathing in infusions of madder, rhubarb, and turmeric, that the urine was tinged with these substances. A garlic plaster affected the breath, when every care was taken, by breathing through a tube connected with the exterior of the apartment, that the odour should not be received into the lungs. Dr. Thomas Sewall[5] found the urine coloured, after bathing the feet in infusion of madder, and the hands in infusions of madder and rhubarb. Dr. Mussey[6] proved, that if the body be immersed in a decoction of mad-

[1] Op. cit., p. 55.

[2] Principles of Human Physiology, Amer. edit., p. 148, Philad., 1855.

[3] Parent-Duchatelet, Hygiène Publique, Paris, 1836; and the remarks of the author in his Human Health, p. 77, Philad., 1844.

[4] New York Med. Repos., vols. i. and iii. 1810–11.

[5] Med. and Physical Journ., xxxi. 80, Lond., 1814.

[6] Philad. Medical and Physical Journal, i. 288, Philad., 1808.

der, the substance may be detected in the urine, by using an appropriate test. Dr. Barton found, that frogs, confined in dry glass vessels, became enfeebled, diminished in size, and unable to leap; but that, on the introduction of a small quantity of water, they soon acquired their wonted vigour, became plump, and as lively as usual in their motions.[1] M. W. F. Edwards[2] of Paris, is, also, in favour of absorption being carried on by the skin to a considerable extent.

To deny cutaneous absorption altogether is impossible. It is a channel, in fact, by which we introduce one of our most active remedial agents into the system;—and it has not unfrequently happened, where due caution has been omitted, that the noxious effects of different mineral and other poisons have been developed by their application to the surface, but it is by no means common or easy, when the cuticle is sound, unless the substance employed possesses unusually penetrating properties. M. Chaussier found, that to kill an animal, it is sufficient to make sulphuretted hydrogen gas act on the surface of the body, taking care that none gets into the air-passages: the researches of Prof. J. K. Mitchell[3] have also shown that this gas is powerfully penetrant. Unless, however, the substances, in contact with the epidermis, are of such a nature as to attack its chemical composition, there is usually no extensive absorption.

It is only of comparatively late years, that physiologists have ventured to deny, that the water of a bath, or the moisture from a damp atmosphere, is taken up under ordinary circumstances; and if, in such cases, the body appears to have increased in weight, it is affirmed, and with some appearance of truth, that this may be owing to diminution of the cutaneous transpiration. It is, indeed, probable, that one great use of the epidermis is to prevent the inconveniences to which we should necessarily be liable, were such absorption easy. This is confirmed by the fact, that if the skin be deprived of the epidermis, and the vessels that creep on the outer surface of the true skin be thus exposed, absorption occurs as rapidly as elsewhere. J. Müller affirms, that saline solutions applied to the corium penetrate the capillaries in a second of time. To insure this result in inoculation and vaccination, the matter is always placed beneath the cuticle; and, indeed, the small vessels are generally slightly wounded, so that the virus gets immediately into the venous blood. Yet—it is proper to remark—the lizard, whose skin is scaly, after having lost weight by exposure to air, recovers its weight and plumpness when placed in contact with water; and if the scaly skin of the lizard permits such absorption, M. Edwards thinks it impossible not to attribute this property to the cuticle of man. When the epidermis is removed, and the system is affected by substances placed in contact with the true skin, we have the *endermic method* of medication.

M. Séguin[4] instituted a series of experiments to demonstrate the absorbent or non-absorbent action of the skin. His conclusion was, that

[1] Klapp, Inaugural Essay on Cuticular Absorption, p. 30, Philad., 1805.
[2] Sur l'Influence des Agens Physiques; or Drs. Hodgkin and Fisher's translation, p. 61, and p. 187, &c., Lond., 1832.
[3] Amer. Journal of the Med. Sciences, vii. 44; and p. 68 of this work.
[4] Annales de Chimie, xc. 185.

water is not absorbed, and that the epidermis is a natural obstacle to the action. To discover, whether this was the case as regarded other fluids, he experimented on individuals labouring under venereal affections, who immersed their feet and legs in a bath, composed of sixteen pints of water and three drachms of corrosive chloride of mercury, for an hour or two, twice a day. Thirteen, subjected to the treatment for twenty-eight days, gave no signs of absorption; the fourteenth was manifestly affected, but he had itchy excoriations on the legs; and the same was the case with two others. As a general rule, absorption exhibited itself in those only whose epidermis was not in a state of integrity. At the temperature of 74° Fahrenheit, however, the sublimate was occasionally absorbed, but never the water. From other experiments, it appeared evident, that the most irritating substances, and those most disposed to combine with the epidermis, were partly absorbed, whilst others were apparently not. Having weighed a drachm (seventy-two grains, *poids de marc*) of calomel, and the same quantity of camboge, scammony, salt of alembroth, and tartar emetic, M. Séguin placed an individual on his back, washed the skin of the abdomen carefully, and applied to it these substances at some distance from each other, covering each with a watch-glass, and maintaining the whole *in situ* by a linen roller. The heat of the room was kept at 65°. M. Séguin remained with the patient, in order that the substances should not be displaced: and he protracted the experiment for ten hours and a quarter. The glasses were then removed, and the substances carefully collected and weighed. The calomel was reduced to $71\frac{1}{2}$ grains. The scammony weighed $71\frac{3}{9}$; the camboge, 71; the salt of alembroth, 62 grains,[1] and the tartar emetic 67 grains.[2]

It requires, then, in order that matters shall be absorbed by the skin, that they shall be kept in contact with it, so as to penetrate its pores, or the channels by which the cutaneous transpiration exudes; or else that they shall be forced through the cuticle by friction,—the *iatraliptic mode*. In this way, the substance comes in contact with the cutaneous vessels, and enters them probably by imbibition. Certain it is, that mercury has been detected in the venous blood by Colson, Christison, Cantu, Autenrieth, Zeller, Schubarth, and others.[3]

Not long after the period that M. Séguin was engaged in his experiments, Dr. Rousseau,[4] of Philadelphia, contested the existence of absorption through the epidermis, and attempted to show, in opposition to the experiments we have detailed, that the pulmonary organs, and not the skin, are the passages by which certain substances enter the system. By cutting off all communication with the lungs, which he effected by breathing through a tube communicating with the atmosphere on the outside of the chamber, he found, that although the surface of the body was bathed with the juice of garlic, or the spirit of turpentine, none of the qualities of these fluids could be detected, either in the urine, or the serum of the blood. From subsequent experiments,

[1] Several pimples were excited on the part to which it was applied.

[2] Magendie's Précis, &c., ii. 262.

[3] The author's General Therapeutics and Materia Medica, 5th edit., i. 108, Philad., 1853.

[4] Experimental Dissert. on Absorption, Philad., 1800.

performed by Dr. Rousseau, assisted by Dr. Samuel B. Smith,[1] and many of which Professor Chapman[2] witnessed, the following results were deduced. *First*, That of all the substances employed, madder and rhubarb were those only that affected the urine,—the latter of the two more readily entering the system; and *secondly*, that the power of absorption is limited to a very small portion of the surface of the body. The only parts, indeed, that seemed to possess it, were the spaces between the middle of the thigh and hip, and between the middle of the arm and shoulder. Topical bathing, with a decoction of rhubarb or madder, and poultices of these substances applied to the back, abdomen, sides, or shoulders, produced no change in the urine; nor did immersion of the feet and hands for several hours in a bath of the same materials afford the slightest proof of absorption.

From these and other facts, sufficiently discrepant it is true, we are justified in concluding, that cuticular absorption, under ordinary circumstances, is not easy; but we can readily conceive, from the facility with which water soaks through animal tissues, that if the animal body be immersed sufficiently long in it, and especially if the vessels have been previously drained, imbibition may take place to a considerable extent. This, however, would be a physical absorption, and might be effected as well in the dead as in the living body.

b. *Other Accidental Absorptions.*

Amongst the adventitious absorptions have been classed all those that are exerted upon substances retained in the excretory ducts, or situate in parts not natural to them. The bile, arrested in one of the biliary ducts, affords us, in jaundice, a familiar example of such absorption by the positive existence of bile in the bloodvessels; although the yellow colour has been gratuitously supposed to be caused by an altered condition of the red globules, and not by the presence of bile. This condition of the red globules would account for some of the symptoms,—as the yellow colour of the skin, and urine,—but it does not explain the clayey appearance, which the evacuations present, and which has been properly ascribed to the absence of the biliary secretion. We have, moreover, examples of this kind of absorption, where blood is effused into the areolar membrane, as in the case of a common sprain, or in those accumulations of fluid in various cavities, that are found to disappear by time;—the serous portion being taken up at first with some of the colouring matter, and, ultimately, the fibrin. In the case of accumulation of the serous fluid that naturally lubricates cavities, it is of such a character—the aqueous portion at least—as to be imbibed with facility, and probably passes into the veins, in this manner,—the functions of exhalation and absorption consisting mainly, in such case, of transudation and imbibition.

But absorption is not confined to these fluids. It must, of course, be exerted on all morbid deposits; and it is to excite the action of the absorbents, that our remedial agents are directed. This absorption—in the case of solids—is of the interstitial kind; and, as the morbid

[1] Philad. Med. Museum, i. 34, Philad., 1811.
[2] Elements of Therapeutics and Materia Medica, 6th edit., i. 65, Philad., 1831.

formation has to undergo an action of elaboration, it ought to be referred to lymphatic agency.

To conclude the function of absorption:—All the products,—whether the absorption has been chyliferous, lymphatic, or venous,—are united in the venous system, and form part of venous blood. This fluid must, consequently, be variable in its composition, in proportion to the quantity of heterogeneous materials taken up by the veins, and the activity of chyliferous and lymphatic absorption. It is also clear, that, between the parts of the venous system into which the supra-hepatic veins,—loaded with the products of intestinal absorption of fluids,—enter, and the opening of the thoracic duct into the subclavian, the blood must differ materially from that which flows in other parts of the system. All, however, undergo admixture in their passage through the heart; and all are converted into arterial blood by the function, that will next engage us.

CHAPTER III.

RESPIRATION.

The consideration of the function of absorption has shown how the different products of nutritive absorption reach the venous blood. By simple admixture with this fluid they do not become converted into a substance, capable of supplying the losses sustained by the frame from the different excretions. Nothing is better established than the fact, that no being, and no part of any being, can continue its functions unless supplied with blood, that has become *arterial* by exposure to air. It is in the lungs, that the absorbed matters undergo their final conversion into that fluid,—by a function, which has been termed *hæmatosis*, the great object of that which we have now to investigate—Respiration. This conversion is occasioned by the venous blood of the pulmonary vessels coming in contact with air in the air-cells of the lungs, during which the blood gives to the air some of its constituents, and, in return, the air parts with its elements to the blood.

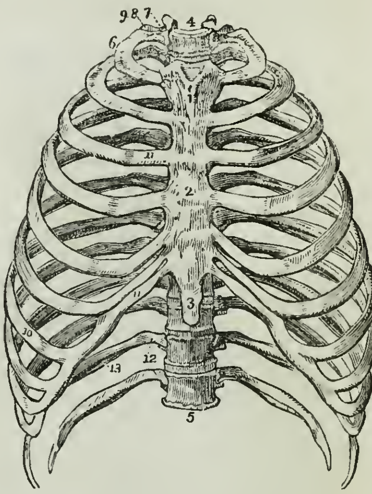
To comprehend this mysterious process, we must be acquainted with the pulmonary apparatus, as well as with the properties of atmospheric air, and the mode in which the contact between it and the blood is effected.

1. ANATOMY OF THE RESPIRATORY ORGANS.

The *thorax* or *chest* contains the lungs,—the great agents of respiration. It is of a conical shape, the apex of the cone being formed by the neck, and the base by a muscle, which has already been referred to more than once,—the *diaphragm*.

The osseous framework, Fig. 76, is formed, *posteriorly*, of twelve dorsal vertebræ; *anteriorly*, of the sternum, originally composed of eight or nine pieces; and *laterally*, of twelve ribs on each side, passing from the vertebræ to, or towards, the sternum. Of these, the seven uppermost extend the whole distance from the spine to the breast-bone, and are called *true* or *sternal*, and at times, *vertebro-sternal ribs*. They become larger as they descend, and are situate more obliquely in regard to the spine. The other five, called *false* or *asternal*, do not proceed as far as the sternum; the cartilages of three of them join that of the seventh true rib, whilst the two lowest have no union with those above them, and are, therefore, called *floating ribs*. These false ribs become shorter and shorter as we descend; so that the seventh true rib may be regarded as the common base of two cones, formed by the true and false ribs respectively.

Fig. 76.



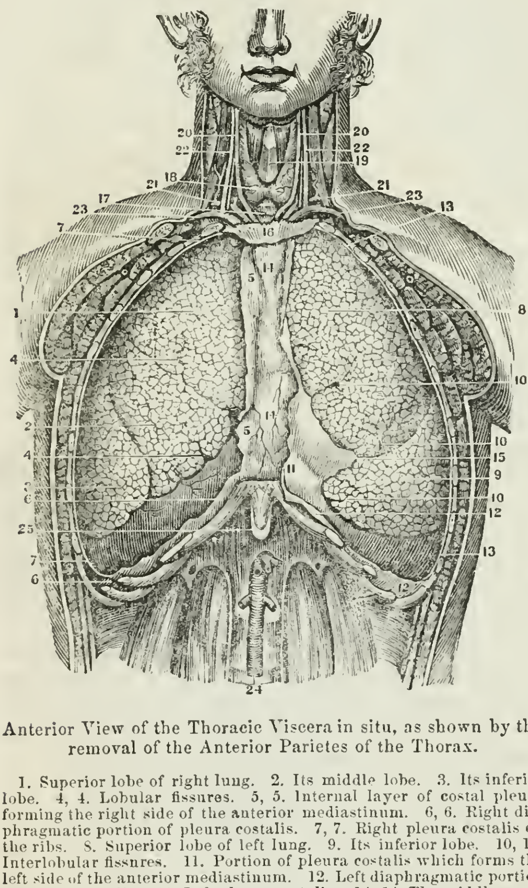
Anterior View of Thorax.

1. Superior piece of sternum. 2. Middle piece. 3. Inferior piece, or ensiform cartilage. 4. First dorsal vertebra. 5. Last dorsal vertebra. 6. First rib. 7. Its head. 8. Its neck, resting against transverse process of first dorsal vertebra. 9. Its tuberosity. 10. Seventh or last true rib. 11. Costal cartilages of true ribs. 12. Two last false ribs—floating ribs. 13. The groove along lower border of rib for lodgment of intercostal vessels and nerve.

The different bones constituting the thorax are so articulated as to admit of motion, and thus of dilatation and contraction of the cavity. The motion of the vertebræ on each other is described under another head. It is not materially concerned in the respiratory movements. The articulation of the ribs with the spine and sternum demands attention. They are articulated with the spine in two places,—at the *capitulum* or head, and at the *tubercle*. In the former of these, the extremity of the ribs, encrusted with cartilage, is received into a depression, similarly encrusted, at the side of the spine. One half of this depression is in the body of the upper vertebra; the other half in the one beneath it; and, consequently, partly in the intervertebral fibro-cartilage between the two. The joint is rendered secure by various ligaments; but it can move readily up and down on the spine. In the first, eleventh, and twelfth ribs, the articulations are with single vertebræ respectively. In the second articulation, the tubercle of the rib, also encrusted with cartilage, is received into a cavity in the transverse process of each corresponding vertebra; and the joint is rendered strong by three distinct ligaments. In the eleventh and twelfth ribs, this articulation is wanting. The articulation of the ribs with the sternum is effected by an intermediate cartilage, which becomes gradually longer, from the first to the tenth ribs, as seen in Fig. 76. The end of the cartilage is received into a cavity at the side of the sternum; and the junction is strengthened by an anterior and a posterior ligament. This articulation does not admit of much motion; but the existence of a synovial membrane shows, that it is destined for some.

The cavity of the thorax is completed by muscles. In the intervals between the ribs are two planes, whose fibres pass in inverse directions, and cross each other. These are the *intercostals*. The diaphragm forms the septum between the thorax and abdomen. Above, the cavity is open; and through the opening numerous vessels and nerves enter. The muscles, concerned in the respiratory function, are numerous. The most important of them is the *diaphragm*. It is attached, by its circumference, around the base of the chest; but its centre rises into the thorax; and, during its state of relaxation, forms an arch, the middle of which is opposite the inferior extremity of the sternum. It is tendinous in its centre, and is attached by two fasciculi, called *pillars*, to the spine,—to the bodies of the first two lumbar vertebræ. It has three apertures; one before for the passage of the vena cava inferior; and two behind, between the pillars, for the passage of the œsophagus and aorta. The other great muscles of respiration are the *serratus posticus inferior*, *serratus posticus superior*, *levatores costarum*, *intercostal muscles*, *infra-costales*, and *triangularis sterni* or *sterno-costalis;* but, in an excited condition of respiration, all the muscles, that raise and depress the ribs, directly or indirectly, participate — as the *scaleni*, *sterno-mastoidei*, *pectoralis*, (*major* and *minor*,) *serratus major anticus*, *abdominal muscles*, &c.

Fig. 77.



Anterior View of the Thoracic Viscera in situ, as shown by the removal of the Anterior Parietes of the Thorax.

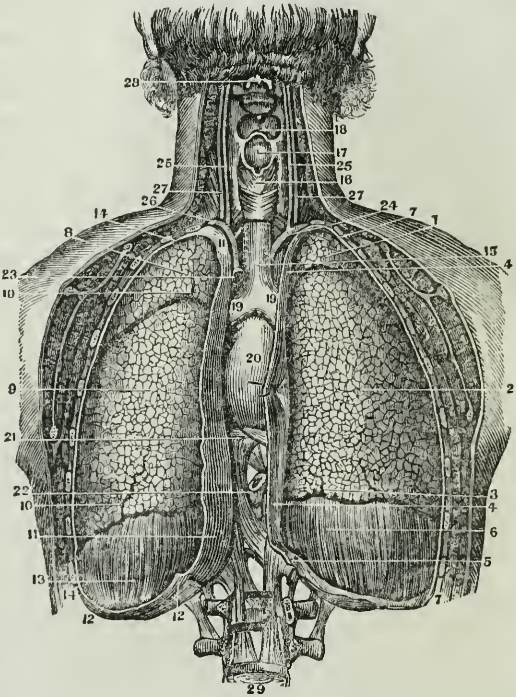
1. Superior lobe of right lung. 2. Its middle lobe. 3. Its inferior lobe. 4, 4. Lobular fissures. 5, 5. Internal layer of costal pleura forming the right side of the anterior mediastinum. 6, 6. Right diaphragmatic portion of pleura costalis. 7, 7. Right pleura costalis on the ribs. 8. Superior lobe of left lung. 9. Its inferior lobe. 10, 10. Interlobular fissures. 11. Portion of pleura costalis which forms the left side of the anterior mediastinum. 12. Left diaphragmatic portion of pleura costalis. 13. Left pleura costalis. 14, 14. The middle space between the pleuræ, known as the anterior mediastinum. 15. Pericardium. 16. Fibrous partition over which the pleuræ are reflected. 17. Trachea. 18. Thyroid gland. 19. Anterior portion of thyroid cartilage. 20. Primitive carotid artery. 21. Subclavian vein. 22. Internal jugular vein. 23. Brachio-cephalic vein. 24. Abdominal aorta. 25. Xiphoid cartilage.

In the structure of the *lungs*, as M. Magendie[1] has remarked, nature has resolved a mechanical problem of extreme difficulty. The problem was,—to establish an immense surface of contact between the blood and air, in the small space occupied by the lungs. The admirable arrangement adopted consists in this,—that each of the minute vessels, in which the pulmonary artery terminates and the pul-

[1] Précis, &c., ii. 307.

monary veins originate, is surrounded on every side by air. The lungs are two organs of considerable size, situate in the lateral parts of the chest, and subdivided into lobes and lobules, the shape and number of which cannot be readily determined. They are termed *right* and *left*, respectively, according to the side of the cavity of the chest which they occupy. The former consists of three lobes; the latter of two. Each of these exactly fills the corresponding cavity of the pleura; and they are separated from each other by a duplicature of the pleura—(the serous membrane that lines the chest, and is reflected over the lungs)—and by the heart. The colour of the lungs is generally of a marble blue; and the exterior is furrowed by figures of hexagonal shape. The appearance is not, however, the same at all ages, and under all circumstances. In infancy, they are of a pale red; in youth, of a darker colour; and in old age, of a livid blue.

Fig. 78.

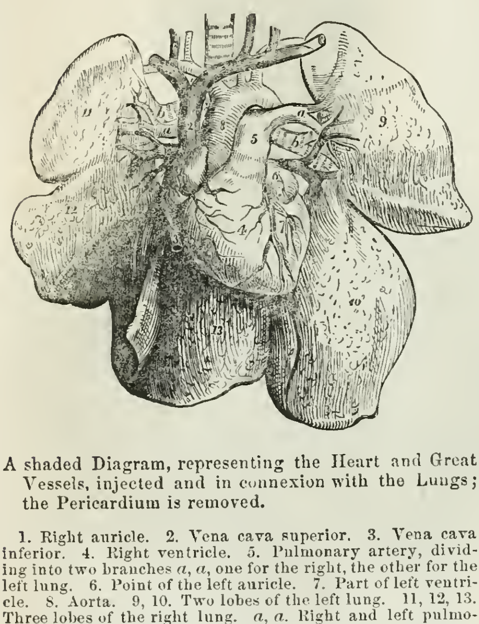


Posterior View of the Thoracic Viscera, showing their relative positions by the removal of the Posterior Portion of the Parietes of the Thorax.

1, 2. Upper and lower lobes of right lung. 3. Interlobular fissures. 4. Internal portion of pleura costalis, forming one of the sides of posterior mediastinum. 5. Twelfth rib and lesser diaphragm. 6. Reflection of the pleura over the greater muscle of the diaphragm on the right side. 7, 7. Right pleura costalis adhering to the ribs. 8, 9. The two lobes of the left lung. 10, 10. Interlobular fissures. 11, 11. Left pleura, forming the parietes of the posterior mediastinum. 12, 13. Its réflections over the diaphragm on this side. 14, 14. Left pleura costalis on the parietes of the chest. 15. Trachea. 16. Larynx. 17. Opening of the larynx and the epiglottic cartilage in situ. 18. Root and top of the tongue. 19, 19. Right and left bronchia. 20. The heart enclosed in pericardium. 21. Upper portion of diaphragm on which it rests. 22. Section of œsophagus. 23. Section of aorta. 24. Arteria innominata. 25. Primitive carotid arteries. 26. Subclavian arteries. 27. Internal jugular veins. 28. Second cervical vertebra. 29. Fourth lumbar.

The elements that compose them are;—the ramifications of the trachea; those of the pulmonary artery and pulmonary veins, besides the organic elements, that appertain to every living structure,—arteries, veins, lymphatics, nerves, and areolar tissue. The ramifications of the windpipe form the cavity of the organ of respiration. The trachea is continuous with the larynx, from which it receives the external air conveyed to it by the mouth and nose. It passes down to the thorax, at the anterior part of the neck, and bifurcates opposite the second dorsal vertebra, forming two large canals called *bronchi* or *bronchia*. One of these goes to each lung; and, after numerous subdivisions, becomes imperceptible; hence, the multitudinous speculations that have been indulged regarding the mode in which the bronchial ramifications terminate. Malpighi[1] believed, that they form vesicles, at the inner surface of which the pulmonary artery ramifies. Reisseisen[2] describes the vesicles as of a cylindrical, and somewhat rounded figure; and states, that they do not communicate with each other. Helvetius,[3] on the other hand, affirmed, that they end in cells, formed by the different constituent elements of the lung,—the cells having no determinate shape, or regular connexion with each other; whilst M. Magendie[4] asserts, that the minute bronchial division, which arrives at a lobe, does not enter it, but terminates suddenly as soon as it has reached the parenchyma; and, he remarks, that as the bronchus does not penetrate the spongy tissue of the lung, it is not probable, that the surface of the cells, with which the air comes in contact, is lined by a prolongation of the mucous coat, which forms the inner membrane of the air-passages. Mr. Hassall,[5] however, contrary to the opinion of most observers, and—as will be seen—to that of Mr. Rainey, one of the most recent of them, affirms, that in sections of fresh lungs "it is a very easy matter not merely to determine the existence of epithelium in the air-cells, but also the fact of its cylinder and ciliated form and character," and this "fact" of the epithelium extending from the bronchial tubes into them —he adds—would seem in itself to imply that the mucous membrane also lines them.

Fig. 79.



A shaded Diagram, representing the Heart and Great Vessels, injected and in connexion with the Lungs; the Pericardium is removed.

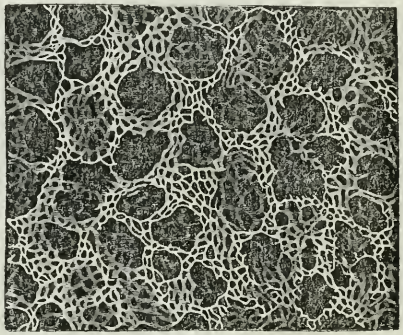
1. Right auricle. 2. Vena cava superior. 3. Vena cava inferior. 4. Right ventricle. 5. Pulmonary artery, dividing into two branches *a*, *a*, one for the right, the other for the left lung. 6. Point of the left auricle. 7. Part of left ventricle. 8. Aorta. 9, 10. Two lobes of the left lung. 11, 12, 13. Three lobes of the right lung. *a*, *a*. Right and left pulmonary arteries. *b*, *b*. Right and left bronchi. *v*, *v*. Right and left pulmonary veins. The relative position of these three vessels is seen to differ on the two sides.

The ramifications of the pulmonary artery are another constituent element of the lung. This vessel arises from the right ventricle of the heart, and, at a short distance from that organ, divides into two branches; one passing to each lung. Each branch accompanies the corresponding bronchus in all its divisions; and, at length, becomes capillary and imperceptible. Its termination, also, has given rise to

[1] Epist. de Pulmon., i. 133.
[2] Ueber den Bau der Lungen, u. s. w., Berlin, 1822; also, in Latin, Berl., 1822.
[3] Mémoires de l'Académ. pour 1718, p. 18.
[4] Précis, &c., ii. 309.
[5] The Microscopic Anatomy of the Human Body in Health and Disease, part xii. p. 381, London, 1848.

conjecture. Malpighi conceived it to end at the mucous surface of the bronchi in an extremely delicate network, which he called *rete mirabile;* and this was, likewise, the opinion of Reisseisen. Bichat[1] admitted at the extremities of the pulmonary artery, and between that artery and the veins of the same name, vessels of a more delicate character, which he conceived to be the agents of hæmatosis, and called the *capillary system of the lungs.* This, however, is nothing more than the fine dense capillary network, formed by the distribution of the artery on the air-cells, from which the *pulmonary veins* arise. Their radicles communicate freely with those of the pulmonary artery. When we observe them distinctly, they are found uniting to constitute larger and larger veins, until they ultimately end in four great trunks, which open into the left auricle of the heart. The pulmonary arteries do not anastomose in their course; and according to Dr. Cammann,[2] the capillaries of one lobule do not communicate with those of another: the interstitial areolar membrane even of the most minute lobules was seen entirely free from colour when a coloured injection was thrown into the vessels.

Fig. 80.



Arrangement of the Capillaries of the Air-cells of the Human Lung.

In addition to these organic constituents, the lung, like other organs, receives arteries, veins, lymphatics, and nerves. It is not nourished by the blood of the pulmonary artery, which is not adapted for the purpose, seeing that it is venous. The *bronchial arteries* are its nutritive vessels. They arise from the aorta, and are distributed to the bronchi.

Around the bronchi, and near where they dip into the tissue of the lung, lymphatic glands—*bronchial glands*—exist, the colour of which is almost black, and with which the few lymphatic vessels, that arise from the superficial and deep-seated parts of the lung, communicate. Haller[3] has traced the efferent vessels of these glands into the thoracic duct.

The nerves, distributed to the lungs, proceed chiefly from the eighth pair or pneumogastric. A few filaments of the great sympathetic are also sent to them. The eighth pair—after having given off the superior laryngeal nerves, and some twigs to the heart—interlaces with numerous branches of the great sympathetic, and forms an extensive nervous network, called *anterior pulmonary plexus.* After this, the nerve gives off the recurrents, and interlaces a second time with branches of the great sympathetic, forming another network, called *posterior pulmonary plexus.* It then proceeds to the stomach, where it terminates. (See Fig. 24.) From these two plexuses the nerves proceed, that are distributed to the lungs. These accompany the bronchi, and are spread

[1] Anatomie Générale, édit. de MM. Béclard, Blandin, and Magendie, ii. 381–386, Paris, 1832.
[2] New York Journal of Medicine, Jan., 1848.
[3] Elem. Physiologiæ, viii. 2, § 15, Lausann. 1764.

chiefly on the mucous membrane of the air-tubes. The lung likewise receives some nerves directly from the three cervical ganglions of the great sympathetic, and from the first thoracic ganglion. In addition to these, a distinct system of nerves—the *respiratory system*, described in another part of this work—is supposed by Sir Charles Bell to be distributed to the multitude of muscles, that are associated in the respiratory function in a voluntary or involuntary manner. This system includes one of the nerves just referred to—the eighth pair—and the phrenic nerves, which are distributed to the diaphragm. The various nerves composing it are intimately connected, so that, in forced or hurried respiration, in coughing, sneezing, &c., they are always associated in action. It will be seen, however, that few physiologists now admit the respiratory system of Sir Charles.

Lastly; the lungs are constituted also of areolar tissue, which has been termed *interlobular tissue;* but it does not differ from areolar tissue in other parts of the body.

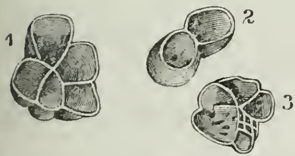
Such are the constituent elements of the pulmonary tissue; but, with regard to the mode in which they are combined to form the intimate texture of the lung we are not wholly instructed. We find, that the lobes are divided into lobules, and these, again, seem to be subdivided almost indefinitely, forming an extremely delicate spongy tissue, the areolæ of which—*air-cells* or *lung-vesicles*—can only be seen by the aid of the microscope.[1] It is generally thought, that the areolæ communicate with each other, and that they are enveloped by the areolar tissue which separates the lobules. M. Magendie[2] inflated a portion of lung, dried and cut it in slices, in order that he might examine the deep-seated cells. These appeared to him to be irregular, and to be formed by the final ramifications of the pulmonary artery, and the primary ramifications of the pulmonary veins; the cells of one lobule communicating with each other, but not with those of another lobule. Professor Horner,[3] of the University of Pennsylvania, has attempted to exhibit that this communication between the cells is lateral. After filling the pulmonary arteries and pulmonary veins with minute injection, the ramifications of the bronchi, with the air-cells, were distended to their natural size by an injection of melted tallow. The latter, being permitted to cool, the lung was cut into slices and dried. The slices were subsequently immersed in spirit of turpentine, and digested at a moderate heat for several days. By this process, all the tallow was removed, and the parts, on being dried, appeared to exhibit the air-cells empty, and, seemingly, of their natural size and shape. Preparations, thus made, appear to show the air-cells to be generally about the twelfth of a line in diameter, and of a spherical form, the cells of each lobule communicating freely, like the cells of fine sponge, by lateral apertures. The lobules, however, only communicate by branches of the bronchi, and not by contiguous cells. This would seem to negative the presumption of some anatomists and physiologists,—as Reisseisen, Blumenbach, Cuvier, &c.,—that each air-cell is insulated, communicating only with the minute bronchus that opens into it; whilst it confirms the views of Haller, Monro (Secundus), Boyer,

[1] Hassall, op. cit. [2] Précis. &c., ii. 309.
[3] American Journal of the Medical Sciences for Feb. 1832, p. 538, and op. cit.

Sprengel, Magendie, Carpenter, and others;—but it is not easy to decide positively, where all is so minute. The observations of Dr. Addison[1] led him to maintain, that the views of Reisseisen and others are certainly true as regards the fœtal lung, in which the ultimate subdivisions of the bronchial tubes terminate in closed extremities. But when an animal has respired, the terminations are said to experience a great change. The membrane composing them offers but slight resistance to the pressure of the air, and is pushed forwards, and distended laterally into rounded inflations, forming a series of cells, which are moulded by mutual pressure into various angular forms, and which communicate freely with each other by large oval apertures. The passages, thus formed, do not communicate otherwise than by their connexion with the same bronchial tube, and the bloodvessels lie between the contiguous walls of each two of them, so that the blood in the capillaries is exposed to air on both sides. It would appear, also, from the researches of M. Bourgery,[2] that the developement of the air-cells,—and, consequently, the capacity for forcible inspiration,—continues in man to the age of thirty, at which time the capacity is greatest. Subsequently, it decreases, especially in those who suffer from cough,—the violence of the respiratory effort often causing rupture of the air-cells, and thus gradually producing the emphysematous state of the lungs so common in old people. After thirty, the capacity for forcible inspiration diminishes one-fifth in the first twenty years; one-fifth more in the next ten; and nearly one-half in the next twenty; and this gradual decrease of capacity for forcible inspiration is true of all persons, although one may have a greater general capacity of respiration than another of the same age. Hence the young person possesses a greater capacity of respiration, as it were, in reserve. The aged have little, and are, therefore, unfit for great exertion.

The observations of Mr. Rainey,[3] which have been adopted by many histologists, lead to the belief, that when the bronchi have attained the diameter of from $\frac{1}{50}$th to $\frac{1}{30}$th of an inch, they gradually lose their cylindrical form, and appear more like irregular passages—termed by Mr. Rainey *intercellular* or *lobular passages*—through the substance of the lung. These passages are clustered with air-cells, which have the appearance of polyhedral alveolar cavities separated by exceedingly thin septa, and do not open into one another by anastomosis or lateral communication, but communicate freely through the medium of the common air-passage to which they belong. The marginal figure (Fig. 81) represents several groups of air-cells from an emphysematous lung, drawn the size of nature from a preparation by Dr. Goddard. The diagrams, Figs. 82 and 83,

Fig. 81.



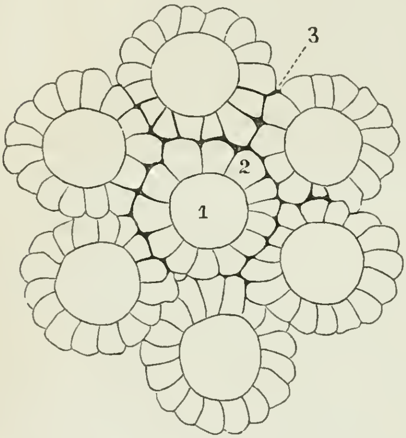
Air-Cells from an Emphysematous Lung.

1. A group of air-cells laid open and exhibiting the fact that there is no lateral intercommunication. 2. Two air-cells; the one to the left exhibits its bronchiolar orifice. 3. Another group: to the left are represented two cells freely communicating from the partition being ruptured by over-distension; and between the two cells to the right are observed some inflated areolæ of areolar tissue.

[1] Proceedings of the Royal Society, March 17, 1842; and Philos. Transact. for 1842.
[2] Gazette Médicale, 16 Juillet, 1842, and Archives Générales de Méd., Mars. 1843.
[3] Medico-Chirurgical Transactions, vol. xxviii., London, 1845. See, also, Todd and Bowman, The Physiological Anat. and Physiology of Man, Pt. iv., p. 390, Lond. 1852.

are given by Dr. Leidy to facilitate the understanding of the relative arrangement of the air-cells to the minute bronchial tubes[1] in this view of the subject. Mr. Rainey affirms, as the result of actual observation, that the mucous lining of the bronchial tube is not continued along the intercellular passages and into the air-cells, a circumstance, which, as he suggests, explains the different effects of inflammation of the tubes and of the air-cells;—the latter, which are lined by fibro-areolar tissue, being accompanied by the exudation of fibrin

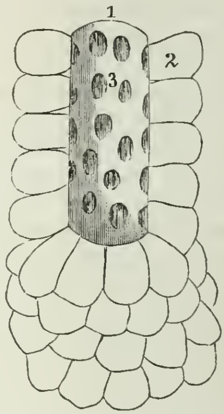
Fig. 82.



Transverse Section of a portion of the Pulmonary Parenchyma.

1. The orifices of bronchioles. 2. The air-cells arranged around the bronchioles, and opening into them, but not communicating laterally. 3. Interspaces filled with areolar tissue, which, when inflated, is liable to be mistaken for the true air-cells.

Fig. 83.



Longitudinal Section of the termination of a Bronchus.

1. The bronchiole, in which are seen the orifices (3) of the air-cells (2) arranged around it and at its termination.

instead of mucus. Anatomists, consequently, who, by the term "air-cell," meant simply the ultimate termination of a bronchial tube; and pathologists, who regarded bronchitis of the terminal extremities of those tubes and pneumonia as essentially alike, were nearer the truth than was generally admitted. The researches of Mr. Rainey led him to conclude—in opposition to Dr. Addison,—that the fœtus, prior to the act of respiration, possesses fully formed air-cells, which are also surrounded by capillary plexuses.

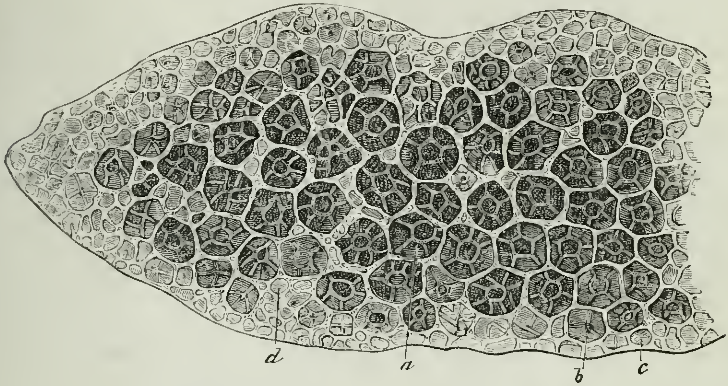
M. Rossignol, who has elaborately described the minute structure of the lungs, insists on the ultimate bronchial ramifications being shaped like an inverted funnel; and hence he calls them infundibula. The cells forming a honeycomb on their interior he calls *alveoli.* Emphysema, according to him, seems to consist in a distension of the passages and cells, and a breaking down and obliteration of the septa, first between the cells of the same passages, and then between neighbouring passages, and even between contiguous lobules.[2]

[1] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Dr. Leidy, ii. 119, Philad., 1849.

[2] The Physiological Anat. and Physiol. of Man, Pt. iv. p. 391, or Amer. edit., Philad., 1853.

Kölliker[1] admits the existence of two layers in the air-cells—a fibrous membrane and an epithelium. The former is manifestly the much

Fig. 84.

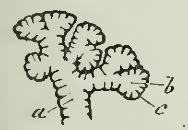


Thin slice from the Pleural Surface of a Cat's Lung, considerably magnified.

At the thin edge, *b c d*, *alveoli* are seen. In the centre (as *a*), where the slice is thicker, alveoli are seen on the walls of *infundibula*.

attenuated mucous membrane and fibrous tunic of the bronchi entirely deprived of the smooth muscles, and consisting of a homogeneous matrix of connective tissue together with elastic fibres and numerous

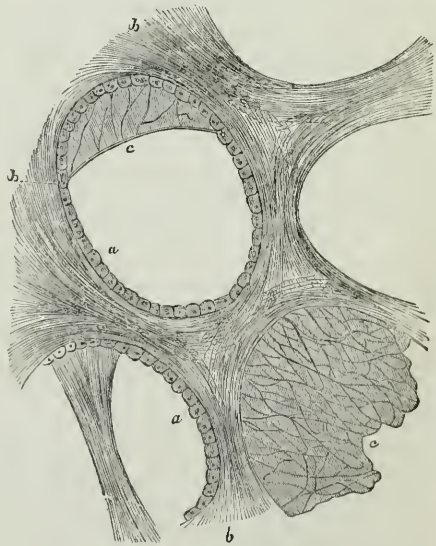
Fig. 85.



Bronchial termination in the Lung of the Dog.

a. Tube (lobular passage) branching towards the infundibula. *b.* One of the infundibula. *c.* Septa projecting inwards on the infundibular wall and forming the alveoli, or cells.

Fig. 86.



Air-cells of Human Lung, with intervening tissues.

a. Epithelium. *b.* Elastic trabeculæ. *c.* Membranous wall, with fine elastic fibres.

[1] Mikroskopische Anatomie, ii. 315, Leipz., 1852, or Amer. edit. of Sydenham Society's edition of Kölliker's Manual of Histology, p. 579, Philad., 1854.

vessels. These fibres run between the air-cells in the form of trabeculæ, and coalesce with the lining membrane so as to strengthen it. The epithelial layer is the tesselated form constituted of minute polygonal cells without cilia. Dr. Thomas Williams, "who has devoted many special examinations to this particular point, is now convinced, that a fine pavement epithelium *does* cover these parts," and such is the opinion of Schröder van der Kolk.[1] The position is contested, however, at great length by Mr. Rainey.[2]

The surface afforded by the air-cells is immense. Hales[3] supposed them to be polyhedral, and about one-hundredth part of an inch in diameter. The surface of the bronchi he estimated at 1635 square inches; and that of the air-cells at 40,000, making the surface of the whole lungs 41,635 square inches or 289 square feet,—equal to 19 times the surface of the body, which, at a medium, he computes to be 15 square feet. Keill[4] estimated the number of cells to be 1,744,186,015; and the surface 21,906 square inches; and Lieberkühn has valued it at the enormous amount of 1500 square feet.[5] M. Rochoux[6] estimates the number of cells at 600,000,000, and that there are about 17,790 grouped around each terminal bronchus. All that we can derive from these mathematical conjectures is, that the extent of surface is surprising, when we consider the small size of the lungs themselves.

The diameter of the lobular passages has been estimated at from the $\frac{1}{100}$th to $\frac{1}{200}$th of an inch, and that of the cells from $\frac{1}{200}$ to $\frac{1}{300}$ of an inch according to the measurements of Messrs. Todd and Bowman. In a preparation of the lung given them by Professor Retzius, they measured $\frac{1}{600}$th; and Dr. Addison makes them from $\frac{1}{200}$th to $\frac{1}{500}$th of an inch.[7] Weber makes their diameter from the $\frac{1}{200}$th to the $\frac{1}{70}$th of an inch; and Kölliker and Carpenter[8] agree with him, while Moleschott estimates them at much less.

Professor Horner[9] has published an account of various experiments, which exhibit the ready communication between the pulmonary air-vesicles and veins. By fixing a pipe into the human trachea, and permitting a column of water to pass gently, he found that the air-cells became distended with water; and that the left side of the heart filled, and the aorta discharged water freely from its cut branches. This experiment he repeated on human lungs on different occasions, and with like results. Very little water flowed from the pulmonary artery. In

[1] Dr. T. Williams, art. Respiration, Organs of, in Cyclop. of Anat. and Physiol., Pt. 45, p. 271, March, 1855.

[2] Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 491.

[3] Statical Essays, i. 242.

[4] Tentam. Med. Phys., p. 80.

[5] Blumenbach, in Elliotson's Physiology, p. 197, Lond., 1835. Mr. E. Wilson (Healthy Skin, Amer. edit., p. 52, Philad., 1854) observes: "The number of air-cells in the two lungs has been estimated at 1,744,000,000, and the extent of the skin which lines the cells and tubes together at 1500 square feet. This calculation of the number of air-cells and the extent of the lining membrane rests, I believe, on the authority of Dr. Addison, of Malvern."!

[6] Gazette Médicale, 4 Janv., 1845.

[7] Todd and Bowman, Op. cit., p. 392.

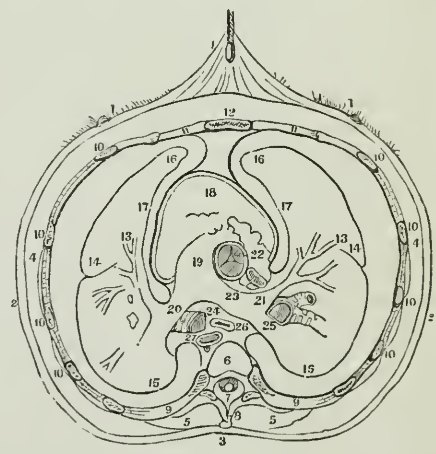
[8] Principles of Human Physiology, p. 285, Amer. edit., Philad., 1855.

[9] Amer. Journ. of the Medical Sciences, April, 1843, p. 332; and Special Anatomy and Histology, 6th edit., ii. 163.

the sheep and the calf, however, when the experiment was practised upon them after they had been pretty thoroughly evacuated of blood, the water passed freely through both the pulmonary veins and the pulmonary arteries. Dr. Horner is disposed to infer, that his experiments exhibit a communication of the pulmonary air-vesicles by a direct route with the pulmonary bloodvessels, especially the veins; but this may well be questioned. It is possible, that such a communication may really have been made by the force of the column of water; and if not so, the passage of the fluid from air-cells to bloodvessels might have been effected through the pores, as in ordinary imbibition, which, we have elsewhere seen, is readily accomplished in the lungs, but not more readily perhaps than in the case of serous and other tissues under favourable circumstances. Hemorrhage by transudation occurs, we know, most rapidly at times through the coats of vessels, whose cohesion has, however, been diminished by disease; and a thinner fluid would of course transude more easily. It can scarcely be doubted, from Dr. Horner's experiments, that a certain arrangement exists betweeen the air-vesicles and the pulmonary veins in man, which allows a more ready imbibition and transudation; but what that arrangement is admits of question.

Each lung is covered by the *pleura*,—a serous membrane analogous to the peritoneum,—and, in birds, a prolongation of the latter. This membrane is reflected from the adjacent surface of the lung to the pericardium which covers the heart, and is then spread over the interior paries of the half of the thorax to which it belongs; lining the ribs and intercostal muscles, and covering the convex or upper surface of the diaphragm. There are, consequently, two pleuræ, each of which is confined to its own half of the thorax, lining its cavity and covering the lung. Behind the sternum, however, they are contiguous to each other, and form the partition called *mediastinum*, which extends between the sternum and spine. Fig. 87 exhibits the boundaries of the two cavities of the pleura. The middle space between is the mediastinum. Within this septum, the

Fig. 87.



Outline of a Transverse Section of the Chest, showing the relative position of the Pleuræ to the Thorax and its Contents.

1. Skin on the front of the chest drawn up by a hook. 2. Skin on the sides of the chest. 3. That on the back. 4. Subcutaneous fat and muscles on the outside of the thorax. 5. Section of the muscles in the vertebral gutter. 6. Section of fifth dorsal vertebra. 7. Spinal canal. 8. Spinous process. 9, 9, 10, 10. Sections of ribs and intercostal muscles. 11. Their cartilages. 12. Sternum. 13. Division of the pulmonary artery. 14. Exterior surface of lungs. 15. Posterior face of lungs. 16. Anterior face of lungs. 17. Inner face of lungs. 18. Anterior face of heart covered by pericardium. 19. Pulmonary artery. 20, 21. Its division into right and left branches. 22. Portion of right auricle. 23. Descending cava cut off at right auricle. 24. Section of left bronchus. 25. Section of right bronchus. 26. Section of œsophagus. 27. Section of thoracic aorta. The space between figures 12 and 18 and the two 16s is the anterior mediastinum, and the space which contains 26 and 27 is the posterior mediastinum. These spaces are formed by the reflections of the pleuræ.

heart, enveloped by the pericardium, is situate, and separates the pleuræ considerably from each other. Anatomists generally subdivide the mediastinum into two regions; one passing from the front of the pericardium to the sternum, called *anterior mediastinum;* the other, from the posterior surface of the pericardium to the dorsal vertebræ,—*posterior mediastinum;* and, by some, the part which is within the circuit of the first ribs, is termed *superior mediastinum.* The second of these contains the most important organs,—the lower end of the trachea, œsophagus, aorta, vena azygos, thoracic duct, and pneumogastric nerves. The portion of the pleura covering each lung, is called *pleura pulmonalis;* that which lines the thorax, *pleura costalis.* It is obvious that, as in the case of the abdomen, the viscera are not in the cavity of the pleura, but external to it; and that there is no communication between the serous sac of one side and that of the other.

The use of the pleura is to attach the lungs by their roots to their respective cavities, and to facilitate their movements. To aid this, the membrane is always lubricated by a fluid, exhaled from its surface. The other surface is attached to the lung in such a manner, that air cannot get between it and the parietes of the thorax. Dr. Stokes[1] admits a proper fibrous tunic of the lungs. In a healthy state, this capsule, although possessing great strength, is transparent, a circumstance in which it differs from the fibrous capsule of the pericardium, and which, Dr. Stokes thinks, has probably led to its being overlooked. It invests the whole of both lungs; covers a portion of the great vessels; and the pericardium seems to be but its continuation,—endowed, in that particular situation, with a greater degree of strength, for purposes that are obvious. It covers the diaphragm where it is more opaque: in connection with the pleura, it lines the ribs; and, turning, forms the mediastina, which are thus shown to consist of four layers,—two serous and two fibrous. It seems, that Dr. Hart, of Dublin, had, for years, demonstrated this tunic to his class.

It was, at one time, the prevalent belief, that air always exists in the cavity of the chest. Galen supported the opinion by the fact, that, having applied a bladder, filled with air, to a wound, which had penetrated the chest, the air was drawn out of the bladder at the time of inspiration. This was also maintained by Hamberger, Hales,[2] and numerous others. The case, alluded to by Galen, is insufficient to establish the position, inasmuch as we have no evidence, that the wound did not also implicate the pulmonary tissue. Since the time of Haller, who opposed the prevalent doctrine by observation and reasoning, the fact of the absence of air in the cavity of the pleura has been generally considered established. It is obvious, that its presence there would materially interfere with the dilatation of the lungs, and thus be productive of fatal consequences; besides, anatomy instructs us, that the lungs lie in pretty close contact with the pleura costalis. When the intercostal muscles are dissected off, and the pleura costalis is exposed, the surface of the lungs is seen in contact with that trans-

[1] On Diseases of the Chest, Part i. p. 460, Dublin, 1837; or Dunglison's American Medical Library edition, p. 301, Philad., 1837.

[2] Statical Essays, ii. 81.

parent membrane; and when the pleura is punctured, the air rushes in, and the lungs retire, in proportion as the air is admitted. This occurs in cases of injuries inflicted upon the chest of the living animal. Moreover, if a dead or living body be placed under water, and the pleura be punctured, so as not to implicate the lungs, it has been found by the experiments of Brunn, Sprögel, Caldani, Sir John Floyer, Haller,[1] and others, that not a bubble of air escapes,—which would necessarily be the case, if air were in the cavity of the pleura.

2. ATMOSPHERIC AIR.

The globe is surrounded everywhere, to the height of fifteen or sixteen leagues, by a rare and transparent fluid called *air;* the total mass of which constitutes the *atmosphere.* Atmospheric air, although invisible, can be proved to possess the ordinary properties of matter; and, amongst these, weight. It also partakes of the character of a fluid, adapting itself to the form of the vessel in which it is contained, and pressing equally in all directions.

As air is possessed of weight, it results, that every body on the earth's surface must be subjected to its pressure; and as it is elastic or capable of yielding to pressure, the part of the atmosphere near the surface must be denser than that above it. As a body, therefore, ascends, the pressure will be diminished; and this accounts for the different feelings experienced by those who ascend lofty mountains, or voyage in balloons into the higher strata of the atmosphere. M. Edwards[2] ascribes part, at least, of the effect produced upon the breathing at great elevations, to the increased evaporation which takes place from the skin and lungs; and in many aerial voyages great inconvenience has certainly been sustained from this cause.

The pressure of the atmosphere at the level of the sea is the result of the whole weight of the atmosphere, and is capable of sustaining a column of water thirty-four feet high, or one of mercury of the height of thirty inches, as in the common *barometer.* This is equal to about fifteen pounds avoirdupois on every square inch of surface; so that the body of a man of ordinary stature, the surface of which Haller estimates to be fifteen square feet, sustains a pressure of 32,400 pounds. Yet, as the elasticity of the air within the body exactly balances or counteracts the pressure from without, he is not sensible of it.

The experiments of Davy, Dalton, Gay Lussac, Humboldt, Despretz, and others, have shown, that pure atmospheric air is composed essentially of two gases, *oxygen* and *nitrogen* or *azote*, which exist in it in the proportion of 21 of the former to 79 of the latter: according to MM. Dumas and Boussingault,[3] 20·81 of the former to 79·19 of the latter: Dr. T. Thomson says 20 of oxygen to 80 of nitrogen; and these proportions have generally been found to prevail in the air whencesoever taken;—whether from the summit of Mont Blanc, the top of Chimborazo, the sandy plains of Egypt, or from an altitude of 23,000 feet in the air.[4] It has been affirmed, indeed, that the proportion of

[1] Element. Physiol., viii. 2, § 3, Lausann., 1764.

[2] De l'Influence des Agens Physiques, &c., p. 493, Paris, 1824.

[3] Annales de Chimie et de Physique, iii. 257, Paris, 1841.

[4] Art. Atmosphere, (Physical and Chemical History,) by Dr. R. M. Patterson, in Amer. Cyclopedia of Practical Medicine and Surgery, vol. ii. p. 526, Philad., 1836.

the gases is subject to a variation of two or three parts in the thousand, in situations where the oxygen is much exposed to absorption, as over the sea, when there is no wind.[1] Chemical analysis has not been able to detect the presence of any emanation from the soil of the most insalubrious regions, or from the bodies of those labouring under the most contagious diseases,—malignant and *material* as such emanations unquestionably must be. The great uniformity in the proportion of the oxygen to the nitrogen in the atmosphere has led to the conclusion, that as there are many processes, which consume the oxygen, there must be some natural agency, by which a quantity of oxygen is produced equal to that consumed. The only source, however, by which oxygen is known to be supplied, is the process of vegetation. A healthy plant absorbs carbonic acid during the day; appropriates the carbon to its own necessities, and gives off the oxygen with which it was combined. This is a nutritive or digestive process; but at the same time the plant is respiring, or consuming oxygen, and giving off carbonic acid. In bright light, however, the former function is so active as to preponderate over, and mask the latter. During the night an opposite effect is produced. Digestion is almost suspended; and respiration is preponderant. Oxygen is then taken from the air, and carbonic acid given off; but the experiments of Davy and Priestley show, that plants, during the twenty-four hours, yield more oxygen than they consume. It seems impossible, however, to look to this as the great cause of equilibrium between the oxygen and the nitrogen. Its influence can extend to a small distance only; yet the uniformity has been found to prevail, as we have seen, in the most elevated regions, and in countries whose arid sands never admit of vegetation.

In addition to the oxygen and nitrogen,—the principal constituents of atmospheric air,—another gas exists in very small proportion, but is always present. This is *carbonic acid*. It was found by De Saussure on Mont Blanc, and by Von Humboldt in air brought down by Garnerin, the aeronaut, from the height of several thousand feet. The proportion is estimated by Dalton not to exceed the $\frac{1}{1000}$th or $\frac{1}{1400}$th of its bulk. In one of the wards of La Pitié, in Paris, which had been kept shut during the night, M. Felix Leblanc[2] found a larger portion of carbonic acid, nearly $\frac{3}{1000}$ths; and in a dormitory of La Salpétrière, the air yielded $\frac{8}{1000}$ths; the largest proportion found by him in hospitals. In the lecture room of the Sorbonne, which is capabable of containing 1000 cubic inches of air, after a lecture an hour and a half long, and at which 900 persons were present, the oxygen was found to have lost 1 in every hundred, although two doors were open; whilst the carbonic acid was increased in rather a greater ratio. In a ward in an institution for children, although the door was half open, and there was an open space in the roof, the air was found to contain $\frac{3}{1000}$ths of carbonic acid, and there was a proportional diminution of oxygen. Dr. Dalton analyzed the air of a room in which 50 candles had been kept burning, and 500 people had

[1] Lewy, Comptes Rendus, 1842; also, Morren, Annales de Chimie et de Physique, xii. 5, Paris, 1844.

[2] Gazette Méd. de Paris, 11 Juin, 1842.

been collected for two hours, and found it to contain one per cent. of carbonic acid.[1] M. Boussingault[2] has made 142 analyses of large quantities of the air of Paris, whence he has drawn the generally admitted conclusion, that the quantity of carbonic acid contained in the air of large towns is not above the average. The average quantity found by him was 3·97 volumes in 10,000. Although largely produced where combustion is extensively going on, and where numbers of persons are congregated together, as in large cities, it becomes so speedily diffused in the atmosphere as not to excite any marked difference between the air in them and in rural districts.[3]

These, then, may be looked upon as the constituents of atmospheric air. There are certain substances, however, which are adventitiously present in variable proportions; and which, with the constitution of the atmosphere as to density and temperature, are the causes of general or local salubrity, or the contrary. Water is one of these. The quantity, according to M. de Saussure, in a cubic foot of air, charged with moisture, at 65° Fahr., is 11 grains. Its amount in the atmosphere is very variable, owing to the continual change of temperature to which the air is subject, and even when the temperature is the same, the quantity of vapour is found to vary, as the air is rarely in a state of saturation. The varying condition as to moisture is indicated by the *hygrometer*. From a comparison of numerous observations, Gay Lussac affirms, that the mean hygrometric state of the atmosphere is such, that the air holds just one-half the moisture necessary for its saturation. In his celebrated aerial voyage, he found it contain but one-eighth. This is, perhaps, the greatest degree of dryness ever noticed.

It has been presumed, that the hygrometric condition of the air has more agency in the production of disease than either the barometric or thermometric. It is not easy to say, which exerts the greatest influence: probably all are concerned; and when we have a union of particular barometric, thermometric, hygrometric, electric, and other conditions, we have certain epidemics existing, which do not prevail under any other combination. When the air is dry, we feel a degree of elasticity and buoyancy; whilst, if it be saturated with moisture—especially during the heat of summer,—languor, lassitude, and indisposition to mental or corporeal exertion are experienced.

In addition to aqueous vapour, numerous emanations from animal and vegetable substances are generally present, especially in the lower strata of the atmosphere; by which the salubrity of the air may be more or less affected. All living bodies, when crowded together, deteriorate the air so much as to render it unfit for the maintenance of the healthy functions. If animals be kept crowded together in ill-ventilated apartments, they speedily sicken. The horse becomes attacked with *glanders;* fowls with *pep*, and sheep with a disease peculiar to them if they be too closely folded. This is probably a principal cause of the insalubrity of cities compared with the country. In them, the

[1] London and Edinb. Philos. Magazine, xii. 405, 1838.

[2] Annales de Chimie et de Physique, Mars, 1844. See, also, M. Lewy, loc. cit.

[3] See Dr. John Reid, article Respiration, in Cyclopædia of Anat. and Physiol., Pt. xxxii. p. 326, London, April, 1848.

air must necessarily be deteriorated by the impracticability of proper ventilation; and this, with the want of due exercise, is a fruitful cause of cachexia—and of tuberculous cachexia; hence, also, it is, that in workhouses and manufactories, diseases dependent on this condition of constitution are prevalent. One of the greatest evidences we possess of the positive insalubrity of towns is in the case of the young. In London, the proportion of those that die annually under five years of age to the whole number of deaths is as much as thirty-eight per cent., and under two years, twenty-eight per cent.; in Paris, under two years of age, twenty-five per cent.; and in Philadelphia and Baltimore, rather less than a third. These estimates may be considered approximations; the proportions varying somewhat, according to the precise year in which they have been taken. Manifest, however, as is the existence of some deleterious principle, in these cases, it has always escaped the researches of the chemist.

Lastly. Air is indispensable to organic existence. No being—animal or vegetable—can continue to live without a due supply of it; nor can any other gas be substituted for it. This is proved by the fact, that all organized bodies cease to exist, if placed in *vacuo*. They require, likewise, renovation of the air, otherwise they die; and if the residual air be examined, it is found diminished in quantity, and to have received a gas, which is totally unfit for life,—*carbonic acid*. The experiments of Hales prove this as regards vegetables; whilst Spallanzani and Vauquelin have confirmed it in the case of the lower animals. The necessity for the presence of air, and its due renewal,—as regards man and the upper classes of animals,—is sufficiently obvious. Not less necessary is a due supply of it to aquatic animals. They can be readily drowned, when the air in the water is consumed, if prevented from coming to the surface. If the fluid be put under the receiver of an air-pump, and the air be withdrawn, or if the vessel be placed so that the air cannot be renewed, the same changes are found to have been produced in it. Hence the necessity for making holes through the ice, where small fish-ponds are frozen over, if we are desirous of preserving the fish alive. The necessity for the renewal of air is not, however, alike imperative in all animals. Whilst the mammalia, birds, fishes, &c., speedily expire, when placed under the receiver of an air-pump, if the receiver be exhausted; the frog is but slightly incommoded. It swells up almost to bursting, but retains its position, and when the air is re-admitted seems to have sustained no injury. The exception, afforded by the amphibious animal to the ordinary effects of destructive agents, we have already had occasion to refer to more than once; and it is exemplified in the fact, now indisputable, that the toad has been found alive in the substance of trees and rocks, where no access of air appeared practicable.

The influence of air on mankind is interesting and important in its hygienic relations, and has accordingly been a topic of study since the days of Hippocrates. In other works, it has been investigated, at considerable length, by the author.[1]

[1] Human Health, Philad., 1844; and American Cyclopædia of Practical Medicine and Surgery, art. Atmosphere, p. 527, Philad., 1836.

3. PHYSIOLOGY OF RESPIRATION.

a. *Mechanical Phenomena of Respiration.*—Within certain limits, the function of respiration is under the influence of volition. The muscles, belonging to it, have consequently been termed *mixed*, as we can at pleasure increase or diminish their action, but cannot arrest it altogether, or for any great length of time. If, by a forced inspiration, we take air into the chest in large quantity, we find it impossible to keep the chest in this condition beyond a certain period. Expiration irresistibly succeeds, and the chest resumes its pristine situation. The same occurs if we expel the air as much as possible from the lungs. The expiratory effort cannot be prolonged indefinitely, and the chest expands in spite of the effort of the will. The most expert divers do not appear capable of suspending the respiratory movements longer than 95 or 100 seconds, or, at the farthest, two minutes. Dr. Lefèvre[1] found the average period of the Turkish divers to be 76 seconds for each man. Yet Dr. Hutchinson[2] states, that a man can take from 230 to 300 cubic inches of fresh air into his lungs, and live upon it without inconvenience for two minutes without breathing. "It is better," he says, "to inspire and expire forcibly five or six times and then hold," with the view of removing as far as possible the old air from the lungs and filling the chest as completely as possible. "For the first fifteen seconds, a giddiness will be experienced; but when this leaves us, we do not find the slightest inconvenience for want of air."

These facts have given rise to two curious and deeply interesting topics of inquiry;—the cause of the first inspiration in the new-born infant;—and of the regular alternation of inspiration and expiration during the remainder of existence? The first of these will fall under consideration when we investigate the physiology of infancy; the latter will claim some attention at present. Haller[3] attempted to account for the phenomenon by the passage of the blood through the lungs being impeded during expiration,—a reflux of blood into the veins, and a degree of pressure upon the brain, being thus induced; hence a painful sensation of suffocation in consequence of which the muscles of inspiration are called into action by the will, for the purpose of enlarging the chest, and, in this way, removing the impediment. The same uneasy feelings, however, ensue from inspiration, if too long protracted: the muscles cease to act, and, by their relaxation, the opposite state of the chest is induced. Whytt[4] conceived, that the passage of the blood through the pulmonary vessels is impeded by expiration, and a sense of anxiety is thus produced. The unpleasant sensation acts as a stimulus upon the nerves of the lungs and the parts connected with them, which arouses the energy of the sentient principle; and this, by acting in a reflex manner, causes contraction of the diaphragm, enlarges the chest, and removes the painful feeling. The muscles then cease to act, in consequence of the stimulus no longer

[1] Loudon's Magazine of Nat. Hist., p. 617, Dec., 1836; and Dunglison's Amer. Med. Intelligencer, p. 30, April 15, 1837.

[2] Art. Thorax, Cyclop. of Anat. and Physiol., iv. 1066, London, 1852.

[3] Elementa Physiologiæ, viii. 4, 17, Lausann., 1764.

[4] An Essay on the Vital and other Involuntary Motions of Animals, sect. viii., Edinb., 1751.

existing. These, and all other methods of accounting for the phenomena, are, however, too pathological. From the first moment of respiration the process appears to be accomplished without the slightest difficulty, and to be as much a part of the instinctive extra-uterine actions of the frame, as circulation, digestion, or absorption. It is obviously an internal sensation, after respiration has been once established; and, like all internal sensations, is inexplicable in our existing state of knowledge. The part which developes the impression is probably the lung, through its ganglionic nerves; and the pneumogastric nerves convey the impression to the brain or spinal marrow, which calls into action the muscles of inspiration. We say, that the action of impression arises in the lungs, and this, from some internal cause, connected with the office to be filled in the economy; but in so saying we sufficiently exhibit our total want of acquaintance with its nature.

The movements of inspiration and expiration, which, together, constitute the function of respiration, are entirely accomplished by the dilatation and contraction of the thorax. Air enters the chest when the latter is expanded; and is driven out when the chest is restored to its ordinary dimensions;—the thorax thus seeming to act like an ordinary pair of bellows with the valve stopped: when the sides are separated, the air enters at the nozzle, and when they are brought together, it is forced out.

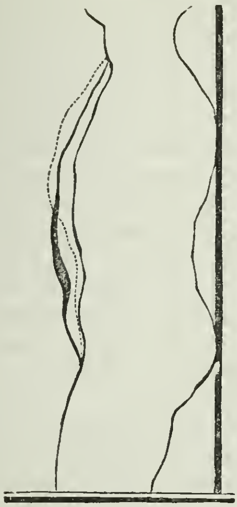
(1.) INSPIRATION.

The augmentation of the capacity of the thorax, which constitutes inspiration, may be effected to a greater or less extent, according to the number of muscles that are thrown into action. The chest may, for example, be dilated by the diaphragm alone. This muscle, as we have seen, in its ordinary relaxed condition, is convex towards the chest. When, however, it contracts, it becomes more horizontal; in this manner augmenting the cavity of the chest in a vertical direction. The sides or lateral portions of the diaphragm, which are fleshy and correspond to the lungs, descend more in this movement than the central tendinous portion, which is moreover kept immovable by its attachment to the sternum, and its union with the pericardium. In the gentlest of all breathing, the diaphragm appears to be the sole agent of inspiration; and in cases of inflammation of the pleura costalis, or of fractured rib, our endeavours are directed to the prevention of any elevation of the ribs by which the diseased part might be put upon the stretch. Generally, however, as the diaphragm descends, the viscera of the abdomen are compressed; the abdominal muscles relaxed; the abdomen is rendered more prominent, and the ribs and the breast bone are raised so that the latter is protruded. When the diaphragm acts, and, in addition, the ribs and sternum are raised, the cavity of the chest is still farther augmented.

In young children, inspiration is effected almost wholly by the diaphragm; and as in diaphragmatic breathing the movement of the parietes of the abdomen is more marked than that of any other part, this has been termed the *abdominal mode* or *type* of respiration.

In adult men, the lower part of the chest and sternum move more largely than in women; who, owing to greater mobility of the first rib, have a more extensive movement of the upper than of the lower part

Fig. 88.



The Changes of the Thoracic and Abdominal Walls of the Male during Respiration.

The back is supposed to be fixed in order to throw forward the respiratory movement as much as possible. The outer black continuous line in front represents the ordinary breathing movement: the anterior margin of it being the boundary of *inspiration*, the posterior margin the limit of *expiration*. The line is thicker over the abdomen, since the ordinary respiratory movement is chiefly abdominal: thin over the chest, for there is less movement over that region. The dotted line indicates the movement on deep inspiration, during which the sternum advances, while the abdomen recedes.

Fig. 89.

The Respiratory Movements in the Female.

The lines indicate the same changes as in the last figure. The thickness of the continuous line over the sternum shows the larger extent of the ordinary breathing movement over that region in the female than in the male.

of the chest,—an arrangement which, it has been suggested, may have for its object the providing of sufficient space for respiration when the lower part of the chest is encroached upon by the pregnant uterus. The former is called by MM. Beau and Maissiat the *costo-inferior* or *inferior costal;* the latter the *costo-superior* or *superior costal* type of respiration.[1]

From the admeasurements of Mr. Sibson[2] it appears, that in health the inspiratory movement of the walls of the chest, during tranquil breathing, is only from two to six-hundredths of an inch; whilst that of the abdomen is about three-tenths of an inch. During a deep inspiration, the expansive motion of the walls of the chest is, in front, about one inch; and at the sides about two-thirds of an inch; and that of the abdomen about one inch. The expansion of the two sides of the chest is nearly equal; the left side does not, however, expand quite so much as the right over the lower two-thirds, owing to the position of the heart.

[1] Archives Générales de Médecine, iii. 263, Paris, 1843; also, Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 127, Philad., 1853.
[2] Provincial Medical and Surgical Journal, Sept. 5, 1849.

The mechanism, by which the ribs are elevated, has been productive of more controversy than the subject merits. Haller[1] asserted, that the first rib is immovable, or at least admits of but trifling motion when compared with the others; and he denied that the thorax, as a whole, makes any movement of either elevation or depression; affirming that the ribs are raised successively towards the top of the cavity; and this to a greater extent as they are more distant from the first. M. Magendie,[2] on the other hand, denies that they are elevated in this manner; and endeavours to show that they are all raised at the same time; that the first rib, instead of being the least movable, is the most so; and that the disadvantage, which the lower ribs possess in the movement, by their admitting of less motion in their posterior articulations, is compensated by the greater length of those ribs. This compensation he considers to have its advantages; for as the true ribs, with their cartilages and the sternum, usually move together, and the motion of one of these parts almost always induces that of the rest, it would follow, that if the lower ribs were more movable, they could not execute a more extensive movement than they do; whilst the solidity of the thorax would be diminished.

By the elevation, then, of the ribs, and the depression of the diaphragm, the chest is augmented, and a deeper inspiration effected than when the diaphragm acts singly. In this elevation of the ribs, we see the advantage of their obliquity as regards the spine. Had they been horizontal, or inclined obliquely upwards, any elevation would necessarily have contracted the thoracic cavity, and thus favoured expiration instead of inspiration.

The muscles chiefly concerned in inspiration are the intercostals, and those that arise, either directly or indirectly, from the spine, head, or upper extremities, and that can, in any manner, elevate the thorax. Amongst these are the scaleni antici and postici, levatores costarum, the muscles of the neck, which are attached to the sternum, &c. The elasticity of the cartilages, and the weight of the osseous portions of the parietes of the chest, must afford considerable resistance to the action of the inspiratory muscles in dilating it. It is probable, however, that the estimates of Dr. Hutchinson[3] are far above the reality. He calculates, that the force which the muscles of inspiration have to overcome in ordinary breathing from these sources is probably at least equal to about 100 lbs.; and in deep inspiration to about 300 lbs.; and yet, in these calculations, the additional resistance from the elasticity of the lungs is not taken into the account.

As no air exists in the cavity of the pleura, it necessarily happens, that when the capacity of the chest is augmented, the residuary air, contained in the air-cells of the lungs after expiration, is rarefied; and, in consequence, the denser air without enters the larynx by the mouth and nose, until the air within the lungs has attained the density, which the residuary air had, prior to inspiration,—not that of the external air, as has been affirmed.[4] At the time of inspiration, the glottis opens by

[1] Elementa Physiologiæ, viii. 4, Lausann., 1764.
[2] Précis, &c., 2de édit., ii. 316.
[3] Medico-Chirurgical Transactions, xxix. 205, London, 1846.
[4] Animal Physiology, Library of Useful Knowledge, p. 100, London, 1829.

the relaxation of the arytenoidei muscles, as M. Legallois[1] proved by experiments performed at the *École de Médecine* of Paris. On exposing the glottis of a living animal, the aperture is found to dilate distinctly at each inspiration, and contract at each expiration. If, according to M. Magendie, the eighth pair of nerves be divided low down in the neck, and the dilator muscles of the glottis, which receive their nerves from the recurrents—branches of the eighth pair—be thus paralysed, the aperture is no longer enlarged during inspiration, whilst the constrictors—the arytenoidei muscles, which receive their nerves from the superior laryngeal,—given off above the point of section, preserve their action, and close the glottis more or less completely.

When air is inspired through the mouth, the velum is raised, so as to allow it to pass freely to the glottis; and, in forced inspiration, it is so horizontal as to completely expose the pharynx to view. The physician takes advantage of this in examining morbid affections of those parts, and can often succeed much better in this way than by pressing down the tongue. On the other hand, when inspiration is effected entirely through the nose, the velum palati is depressed until it becomes vertical, and there are no obstacles to the free entrance of the air into the larynx. In such case, where difficulty of breathing exists, the small muscles of the alæ nasi are frequently thrown into violent action, alternately dilating and contracting the apertures of the nostrils: hence this is a common symptom in pulmonary affections.

Mayow[2] conceived, that air enters the lungs in inspiration as it would a bladder put into a pair of bellows, and communicating with the external air by the pipe of the instrument. The lungs, however, are not probably so passive as this view would indicate. In cases of pulmonary hernia, the extruded portion has been observed to dilate and contract in inspiration and expiration. Reisseisen believed this to be owing to muscular fibres, which Meckel and himself conceived to make the whole circuit of the bronchial ramifications. Laennec[3] affirms, that he has endeavoured, without success, to verify the observations of Reisseisen; but that the manifest existence of circular fibres in branches of a moderate size, and the phenomena presented by many kinds of asthma, induce him to consider the temporary constriction and occlusion of the minute bronchial ramifications as a thing established. The muscular action of the lungs may be demonstrated by galvanizing them shortly after they have been taken from the body; when they contract so as to lift up water placed in a tube introduced into the trachea;[4] and it is affirmed by M. Longet[5] and by Volkmann,[6] that they may be made to contract by stimulating their nerves. The latter physiologist tied a glass tube, drawn fine at one end, into the trachea of a decapitated animal; and when the small end was turned to the flame of a candle,

[1] Œuvres, p. 177, Paris, 1824.

[2] Tractatus Quinque, p. 271, Oxon., 1674.

[3] On the Diseases of the Chest, &c., 4th edit., Lond., 1834; reprinted in this country, Philad., 1835.

[4] C. J. B. Williams, Report of the Meeting of the British Association, in Athenæum for 1840, p. 802.

[5] Traité de Physiologie, ii. 328, Paris, 1850.

[6] Art. Nervenphysiologie, in Wagner's Handwörterbuch der Physiologie, 10te Lieferung, s. 586, Braunschweig, 1845.

he galvanized the trunk of the pneumogastric nerve. On each application, the flame was blown upon; and once it was extinguished.

Fig. 90.

Small Bronchial Tube laid open,

Showing the transverse plexiform arrangement of the muscular layer, and its disposition at the orifice of a branch. From a man æt. fifty.—Magnified 2 diam.

In the trachea, an obvious muscular structure exists in the posterior third, where the cartilages are wanting. There it consists of a thin muscular plane,—the trachealis muscle,—the fibres of which pass transversely between the interrupted extremities of the cartilaginous rings of the trachea and bronchi, to which a layer of longitudinal fibres may at times be seen superadded.[1] The use of the transverse muscular tissue, as suggested by Dr. Physick,[2] and after him by M. Cruveilhier and Sir Charles Bell[3], is to diminish the calibre of the air-tubes in expectoration; so that the air having to pass through the contracted portion with greater velocity, its momentum may remove the secretions that are adherent to the mucous membrane. The explanation is ingenious and probably just.

In the larger bronchi the muscles have the form of circular flattened fasciculi, which, except in old people, in whom interstices of different sizes are observable, constitute a completely continuous layer, which are still perceptible in ramifications of from $\frac{1}{10}$th to $\frac{1}{12}$th of a line in diameter.[4]

M. Magendie[5] asserts, that the lung has a constant tendency to return upon itself, and to occupy a smaller space than it fills; and that it consequently exerts a degree of traction on every part of the parietes of the thorax. This traction has but little effect upon the ribs, which cannot yield; but upon the diaphragm it is considerable. It is, in his opinion, the cause why that muscle is always tense, and drawn so as to be vaulted upwards; when the muscle is depressed during contraction, it is compelled to draw down the lungs towards the base of the chest, so that they are stretched, and by virtue of their elasticity have a powerful tendency to return upon themselves, and draw the diaphragm upwards. If a puncture be made into the chest in one of the intercostal spaces, the air will enter the chest through the aperture, and the lung will shrink. By this experiment, the atmospheric pressure is equalized on both surfaces of the lung, and the organ assumes a bulk determined by its elasticity and weight. Owing to this resiliency of the lungs, and to their consequent tendency to recede from the pleura costalis, there is less pressure upon all the parts against which the lungs are applied; and, accordingly, the heart is not exposed to the same degree of pressure as the parts external to the chest; and the degree of pressure is still farther reduced, when the chest is fully dilated, the

[1] Goddard, in Wilson's Anatomist's Vade-Mecum, Amer. edit., p. 404, note, Philad., 1843.

[2] Horner's Lessons in Practical Anat., p. 179, Philad., 1836.

[3] Philos. Transact. for 1832, p. 301.

[4] Kölliker, Mikroskopische Anat., ii. 313, Leipz., 1852; or Amer. edit. of Sydenham Society's translation of Kölliker's Manual of Histology, by Dr. Da Costa, p. 578, Philad., 1854.

[5] Précis, &c., ii. 325.

lungs farther expanded, and their elastic resiliency increased. Dr. Carson[1] states, that in his experiments on calves, sheep, and large dogs, the resiliency of the lungs was found to be balanced by a column of water, varying in height from a foot to a foot and a half; and in rabbits and cats by a column varying in height from six to ten inches.

Many physiologists have pointed out three degrees of inspiration, but it is manifest that there may be innumerable shades between them:—1. *Ordinary gentle inspiration*, owing simply to the action of the diaphragm; or, in addition, to a slight elevation of the chest. 2. *Deep inspiration*, when, with the depression or contraction of the diaphragm, there is evident elevation of the thorax; and, lastly, *forced inspiration*, when the air is strongly drawn in by the rapid dilatation produced by the action of all the respiratory muscles that elevate the chest directly or indirectly.

Trials have been instituted for determining the quantity of air taken into the lungs at an inspiration; and considerable diversity, as might be expected, exists in the evaluations of different experimenters.[2] We have just remarked, that, in the same individual, the inspiration may be gentle, deep, or forced; and, in each case, the quantity of air inspired will necessarily differ. There is, likewise, considerable diversity in individuals; so that an approximation can alone be attained. The following table sufficiently exhibits the discordance on this point. Many, however, of the estimates, which seem so discrepant, may probably be referred to imperfection in the mode of conducting the experiment, as well as to the causes above mentioned:—

	Cubic inches at each Inspiration.		Cubic inches at each Inspiration.
Reil,	42 to 100	Jeffreys,	26
Menzies, Sauvages, Hales, Haller, Ellis, Sprengel, Sömmering, Chaptal Bell, Monro, Blumenbach, Thomson, Bostock,	40	Herbst,	24 to 30
		Herholdt,	20 to 29
		Jurine and Coathupe,	20
		Kite,	17
		Allen and Pepys,	16½
		T. Thomson,	16
		Hutchinson,	16 to 20
		J. Borelli,	15 to 40
		Goodwin,	14
		Valentin,	14 to 92
		Sir H. Davy,	13 to 17
		Lavoisier and Séguin,	13
		Abernethy and Mojon,	12
Jurin,	35 to 38	Vierordt,	10 to 42
Fontana,	35	Keutsch,	6 to 12
Richerand and Cavallo,	30 to 40	Abildgaard,	3
Dalton,	30		

In passing through the mouth, nasal fossæ, pharynx, larynx, trachea, and bronchi, the inspired air acquires nearly the temperature of the body; and, if it be cool, the same quantity by weight occupies a

[1] Philosophical Transactions, for 1820, p. 42.

[2] Dr. Marshall Hall has devised a *pneumatometer* for this purpose. See art. Irritability, in Cyclop. of Anat. and Physiol., July, 1840.

much larger space in the lungs, owing to its rarefaction in those organs. According to Valentin, the temperature of the expired air is 99°·5 Fahr., when breathing an atmosphere of moderate temperature. In its passage, too, it becomes mixed with the halitus, that is constantly exhaled from the mucous membrane of the air-passages: in this condition, it enters the air-cells, and becomes mixed, by diffusion, with the residuary air.

It is obvious, that if we knew the exact capacity of the lungs in an individual in health, we might be able to determine the extent of solidification in pulmonary affections by the diminution in their capacity. Owing, however, to our want of this requisite preliminary knowledge, the test is not of much avail.

(2.) EXPIRATION.

A brief interval elapses after the accomplishment of inspiration, before the reverse movements of expiration succeeds; and the air is expelled from the chest. The great cause of this expulsion is the restoration of the chest to its former dimensions; and the elasticity of the yellow tissue composing the bronchial ramifications, which has been put upon the stretch by the air rushing into them during inspiration. The restoration of the chest to its dimensions may be effected simply by the cessation of the contraction of the muscles, that have raised it, and the elasticity of the cartilages, that connect the bony portions of the ribs with the sternum or breast-bone. In active expiration, however, the ribs are depressed by the contraction of appropriate muscles, and the chest is still farther contracted. The chief expiratory muscles are the triangularis sterni, the broad muscles of the abdomen, rectus abdominis, sacro-lumbalis, longissimus dorsi, serratus posticus inferior, &c. Haller[1] conceived that the ribs, in expiration, are successively depressed towards the last rib; which is first fixed by the abdominal muscles and quadratus lumborum. The intercostal muscles then act, and draw the ribs successively downwards. M. Magendie[2] contests the explanation of Haller; and the truth would seem to be, that the muscles, just mentioned, participate with the intercostals in every expiratory movement. By this action, the capacity of the chest is diminished; the lungs are correspondently pressed upon, and the air issues by the glottis. It has been already remarked, that, during expiration, the arytenoidei muscles contract, and the glottis appears to close. Still, space sufficient is left to permit the exit of the air.

It has been asked:—Is the air expired precisely that which has been taken in by the previous inspiration? Certainly not. It has experienced much change. A portion of the oxygen has disappeared and carbonic acid has taken its place. The amount of the inspired air does not differ largely from that which is expired; and the quantity employed in an ordinary act of inspiration bears—as will be seen—but a small proportion to the residual air. There must be some mode consequently in which the residual air or that occupying the air-cells is changed, and this is probably effected mainly by the mutual diffu-

[1] Element. Physiol., viii. 4, Lausann., 1764. [2] Précis, &c., ii. 324.

sion of gases; which mix readily with each other when either of different densities or different temperatures; and this admixture is doubtless greatly favoured by the respiratory movement. The muscular fibres and the minute bronchial tubes may have an agency in the matter, as suggested by Prof. Draper.[1] Were the parietes of the air-cells possessed of contractile fibres, they might be greatly concerned; but this is not admitted.[2]

Many experiments have been made to determine the change of bulk which air experiences by being respired. According to Sir Humphry Davy,[3] it is diminished, by a single inspiration, from $\frac{1}{70}$th to $\frac{1}{100}$th part of its bulk. Cuvier makes it about $\frac{1}{50}$th; Allen and Pepys a little more than one-half per cent. Berthollet from 0·69 to 3·70 per cent.; and Bostock $\frac{1}{50}$th,—as the average diminution. Assuming this last estimate to be correct, and forty cubic inches to be the quantity drawn into the lungs at each inspiration, it would follow, that half a cubic inch disappears each time we respire. This, in a day, would amount to 14,400 cubic inches, or to rather more than eight cubic feet. The experiments of MM. Dulong and Despretz make the diminution considerable. The latter gentleman placed six small rabbits in forty-nine quarts of air for two hours, at the expiration of which time the air had diminished one quart. A portion of the inspired air must, consequently, be absorbed.

In the ordinary respiration of men from seventeen to thirty-three years old, Valentin[4] has calculated, from the watery vapour contained in the saturated expired air, that the average quantity of air expired in a minute is 400 cubic inches,—the extremes under varying circumstances being 234 and 686 cubic inches, and the average quantity of one ordinary expiration 31·1 cubic inches; the extremes in very tranquil and somewhat hurried respiration 11·4 and 74 cubic inches. Mr. Paget,[5] however, thinks that Mr. Coathupe's[6] estimate of 20 to 25 cubic inches is probably better, inasmuch as it was drawn from the results of respiration continued during a longer period and with less restraint than in the experiments of Valentin.

It has long been an inquiry of interest, especially for the appreciation of encroachments of pulmonary disease, to determine the amount of air expelled from the chest; and different instruments have been devised for the purpose by Kentish, Phöbus, and others.[7] Pulmometry is consequently not new; but it had never been carefully investigated before the interesting experiments made by Dr. Hutchinson[8] with the instrument somewhat unhappily termed by him a *spirometer*, by which he measures the quantity of air expired in a full and forcible expiration, and which he esteems an index of the *vital capacity*, as it expresses the power which a person has of breathing in the exigen-

[1] Amer. Journ. of the Med. Sciences, April, 1852.
[2] Kölliker, Mikroskopische Anatomie, and Amer. edit. of his Manual of Human Histology, by Dr. Da Costa, p. 579, Philad., 1854.
[3] Researches, Chemical and Philosophical, p. 431, Lond., 1800.
[4] Lehrbuch der Physiologie des Menschen, i. 542, Braunschweig, 1844.
[5] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 128, Philad., 1853.
[6] Philos. Magazine, June, 1839.
[7] Fabius [et Buys-Ballot] De Spirometro. Diss. inaug., Amsterdam, 1853.
[8] Medico-Chirurgical Transactions, xxix. p. 237, Lond., 1846; and art. Thorax, in Cycl. of Anat. and Physiol., iv. 1068, Lond., 1852; also, Dr. John Reid, Ibid., p. 339.

cies of active exercise, violence, and disease. From the results of 1923 observations made on males, he has inferred, that for every inch of height—from five feet to six—eight additional cubic inches of air at 60° Fahr. are given out by a forced expiration; so that, he believes, from the height alone of an adult male, he can pronounce what quantity of air he should breathe when healthy. This is a singular result, as it is not easy to see what relation there can be between the height of a person, which is greatly regulated by the length of his legs; and the quantity of air he is capable of respiring. Much must obviously depend upon the degree of nervous power or of muscular activity,[1] but the difference cannot be altogether accounted for in this way; as cases are not uncommon in which men of great muscular powers are below the standard; whilst others, by no means remarkable for such power, greatly exceed it.[2]

Dr. Hutchinson gives the following table of the quantity of air, expelled by the strongest expiration after the deepest inspiration, for every inch of height between five and six feet, as ascertained by actual observation with the spirometer, and as calculated by the rule of progression referred to above.

Height.	From Observation.	Regular Progression.
Ft. in. Ft. in.	*Cub. in.*	*Cub. in.*
5 0 to 5 1	174	174
5 1 " 5 2	177	182
5 2 " 5 3	189	190
5 3 " 5 4	193	198
5 4 " 5 5	201	206
5 5 " 5 6	214	214
5 6 " 5 7	229	222
5 7 " 5 8	228	230
5 8 " 5 9	237	238
5 9 " 5 10	246	246
5 10 " 5 11	247	254
5 11 " 6 0	259	262

Dr. Hutchinson found, that two other conditions influence the quantity of air that passes to and from the lungs in forced voluntary respiration,—weight, and age. The former does not affect the respiratory power of an individual of any height between five feet one inch and five feet eleven inches, until it has increased seven per cent. above the average weight of the body in persons of that height; but, beyond this, it diminishes in the ratio of one cubic inch per pound for the next 35 pounds,—the limit of his calculations. In males of the same height the respiratory power is increased from 15 to 35 years of age; but from 35 to 65 years it decreases nearly 1½ cubic inch for each year;[3] and the results of the examinations are so nearly uniform, that it has been inferred, disease may be suspected in any man who cannot blow out nearly as many cubic inches as the average of those of the same height, even when by external measurement his chest appears to be of full size. The size of the chest is, indeed, stated to afford no good indication of the capacity of expiration. The only exceptions

[1] Prof. S. Jackson, in Med. Examiner, Jan., 1851, p. 51.
[2] Dr. C. Radclyffe Hall, in Transact. of Prov. Med. and Surg. Assoc., 1851.
[3] For the quantity of air inspired and expired in forced respiration, see Hales, Statical Essays, i. 242, and Bostock, System of Physiology, p. 316, Lond., 1836.

among the healthy to the general rule of the direct proportion between the height of the body and the capacity of expiration, are in the cases of fat persons, whose capacity is always low. It was the observation —made by M. Bourgery[1]—that thin men have the greatest capacity of respiration, which first led Dr. Hutchinson to the experiments, that furnished the law given above. He found, that the full expiratory force of a healthy man is commonly about one-third greater than his inspiratory force; and he states, that whenever the expiratory are not stronger than the inspiratory muscles, some disease is present. In examining the results of all his experiments—1500 in number—he found the power of the inspiratory muscles was greatest in men of five feet nine inches in height,—their inspiratory powers being equal, on an average, to a column of 2·75; and their expiratory power to one of 3·97 inches of mercury; whilst in four of the classes, composed generally of active, efficient and healthy individuals, namely Firemen, Metropolitan Police, Thames Police, and Royal Horse Guards, the inspiratory power of the men of five feet seven inches was the greatest, being equal to 3·07 inches of mercury; and those of five feet eight inches to 2·96, or nearly three inches. The average power of the five feet seven inches and five feet eight inches men of all classes examined was only 2·65 inches of mercury. He infers, from all his experiments, that a healthy man of the height of five feet seven inches or five feet eight inches ought to elevate by inspiration a column of mercury of three inches.

The experiments of Valentin[2] and Mendelssohn,[3] as far as they go, confirm those of Dr. Hutchinson.

Attempts have been made to estimate the quantity of air remaining in the lungs after respiration; but the sources of discrepancy are here as numerous as in the cases of inspiration or expiration. Goodwyn[4] estimated it at 109 cubic inches: Menzies[5] at 179; Jurin[6] at 220; Fontana[7] at 40; and Cuvier, after a forced inspiration, at from 100 to 60. Davy[8] concluded, that his lungs, after a forced expiration, still retained 41 cubic inches of air; and after a natural expiration 118 cubic inches; after a natural inspiration, 135; and after a forced inspiration, 254. Vierordt[9] supposes that the residual air after the deepest expiration is about 36.600 cubic inches. By a full forced expiration after a forced inspiration, he expelled 190 cubic inches; after a natural inspiration, 78·5; and after a natural expiration, 67·5. Mr. Julius Jeffreys[10] divides the air of respiration into four quantities—*First*, the *residual air*, or that which cannot be expelled from the lungs, but remains after a full and forcible expiration; which he estimates at 120 cubic inches—*Secondly*, the *supplementary air*,—*reserve air* of Dr. Hutchinson—or

[1] Archiv. Générales de Médecine, Mars, 1843.

[2] Lehrbuch der Physiologie des Menschen, i. 524, Braunschweig, 1844.

[3] Der Mechanismus der Respiration und Circulation, Berlin, 1845; cited by Dr. John Reid, op. cit., p. 336.

[4] Op. citat., p. 36.

[5] Op. cit., p. 31.

[6] Philosoph. Trans., vol. xxx. p. 758.

[7] Philosoph. Trans. for 1799, p. 355.

[8] Op. citat., p. 411.

[9] Art. Respiration, in Wagner's Handwörterbuch der Physiologie, u. s. w. 12te Lieferung, Braunschweig, 1845.

[10] Views upon the Statics of the Human Chest, &c., London, 1843.

that which can be expelled by a forcible expiration, after an ordinary outbreathing, valued at 130 cubic inches—*Thirdly*, the *breath*, or *tidal air*,—*breathing air* of Dr. Hutchinson—valued at 26 cubic inches; and *Fourthly*, the *complementary* or *complemental air*, or that which can be inhaled after an ordinary inspiration, which amounts to 100 cubic inches. This estimate gives 250 cubic inches as the average volume which the chest contains after an ordinary expiration.

It is impossible, from such variable data as the above, to deduce any thing like a satisfactory conclusion; but if we assume with Dr. Bostock, and Dr. Thomson[1] is disposed to adopt the estimate, 170 cubic inches as the quantity that may be forcibly expelled, and that 120 cubic inches will be left in the lungs, we shall have 290 cubic inches as the measure of the lungs in their natural or quiescent state; to this quantity 40 cubic inches are added by each ordinary inspiration, giving 330 cubic inches as the measure of the lungs in their distended state. Hence it would seem, that about one-eighth of the whole contents of the lungs is changed by each respiration; and that rather more than two-thirds can be expelled by a forcible expiration. Supposing that each act of respiration occupies three seconds, or that we respire twenty times in a minute, a quantity of air, rather more than 2¾ times the whole contents of the lungs, will be expelled in a minute, or about four thousand times their bulk in twenty-four hours. The quantity of air respired during this period will be 1,152,000 cubic inches, about 666½ cubic feet. Such is Dr. Bostock's estimate.

It is the residuary air, that gives to the lungs the property of floating on the surface of water, after they have once received the breath of life; and no pressure can force out the air, so as to make them sink. Hence, the chief proofs, whether a child has been born alive or dead, are deduced from the lungs. These constitute *docimasia pulmonum*, Lungenprobe or Athemprobe ("Lung-proof or Respiration-proof") of the Germans.

Expiration, like inspiration, has been divided into three grades; *ordinary*, *free*, and *forced;* but it must necessarily admit of multitudinous shades of difference. In *ordinary* passive respiration, expiration is effected solely by the relaxation of the diaphragm. In *free* active respiration, the muscles that raise the ribs are likewise relaxed, and there is a slight action of the direct expiratory muscles. In *forced* expiration, all the respiratory muscles are thrown into action. In this manner, the air makes its way along the air-passages through the mouth or nostrils, or both; carrying with it a fresh portion of the halitus from the mucous membrane. This it deposits when the atmosphere is colder than the temperature acquired by the respired air, and if the atmosphere be sufficiently cold, as in winter, the vapour becomes condensed as it passes out, and renders expiration visible.

Dr. Hutchinson[2] measured the costal movement during ordinary respiration in healthy males, and found it not to exceed from two to four-tenths of a line. He states, that the difference between the cir-

[1] System of Chemistry, vol. iv.

[2] Medico-Chirurgical Transactions, xxix. 187. Lond., 1846; and art. Thorax, in Cyclop. of Anat. and Physiol., iv. 1080, Lond., 1852.

cumference of an ordinary man's chest measured over the nipples in the two states of a deep inspiration and a deep expiration amounts to three inches; and Valentin,[1] under the same circumstances, found the average difference in the circumference of the chest, measured over the scrobiculus cordis, in seven individuals of the male sex between $17\frac{1}{2}$ and 33 years of age, to be as 1 : 8·29 of the whole circumference.

In the majority of cases, perhaps, the times occupied by the murmurs of inspiration and of expiration will be nearly in the ratio of three to one. Thus, if a healthy person breathes fifteen times in a minute, or once in four seconds, the time occupied by the periods of inspiration, expiration, and repose will be nearly one and a half, a half, and two seconds, respectively. Differences will exist in healthy individuals; but the above may perhaps be esteemed the expression of the general truth. It is important to bear these facts in mind, inasmuch as, in disease, the expiratory murmur is apt to become prolonged, first of all at the expense of the period of repose, and afterwards of that of inspiration;[2]—a circumstance to which attention was first forcibly directed by Dr. James Jackson, Jun., of Boston. Budge[3] does not admit, that the length of inspiration is as great when compared with that of expiration as is given above; and he considers the pause or period of repose to be more apparent than real.

The number of respirations in a given time differs considerably in different individuals. Dr. Hales,[4] Dr. Dalton,[5] Mr. Coathupe,[6] and Dr. Bostock[7] reckon them at twenty. Laënnec from twelve to fifteen. A man, on whom Menzies made experiments, breathed only fourteen times in a minute. Sir Humphry Davy[8] made between twenty-six and twenty-seven in a minute. Dr. Thomson,[9] and Allen and Pepys, about nineteen; and Magendie,[10] fifteen. In 1714 adults of the male sex considered to be in a state of health, Dr. Hutchinson[11] found, that the majority, in the sitting posture, breathed between 16 and 24 in the minute; and of these a great number 20 per minute. Vierordt[12] found the number in his own person to be, on an average, $11\frac{9}{10}$ths when sitting and the mind disengaged; whilst the maximum was 15, and the minimum 9. Our own average is about sixteen; and this is the average, in the adult, assumed by Günther[13] and Berthold.[14] That, deduced from the few observers, who have recorded their observations,—twenty per minute,—

[1] Lehrbuch der Physiologie des Menschen, i. 541, Braunschweig, 1844.
[2] Lectures on the Physical Diagnosis of the Diseases of the Lungs and Heart, by Herbert Davies, M. D., p. 69, London, 1851.
[3] Memoranda der speciellen Physiologie des Menschen, 5te Auflage, S. 60, Weimar, 1853.
[4] Statical Essays, 3d edit., i. 243.
[5] Memoirs of the Literary and Philosophical Society of Manchester, 2d series, ii. 26, Manchester, 1813.
[6] Lond. and Edinb. Philos. Magaz., xiv. 401, 1839.
[7] System of Physiology, p. 321, Lond., 1836.
[8] Researches chiefly concerning Nitrous Oxide, p. 434, Lond., 1800.
[9] System of Chemistry, iv. 604, Glasgow, 1820.
[10] Précis de Physiologie, 2de édit., Paris, 1825.
[11] Op. cit., p. 226.
[12] Wagner's Handwörterbuch der Physiologie, art. Respiration, ii. 834, Braunschweig, 1845.
[13] Lehrbuch der Physiologie des Menschen, 2ter Band, 1ste Abtheil., S. 217, Leipzig, 1848.
[14] Lehrbuch der Physiologie, 3te Auflage, 2ter Theil, S. 227, Götting., 1848.

has generally been taken; but we are satisfied it is above the truth; eighteen would be nearer the general average, and it has accordingly been admitted by many. Eighteen in a minute give twenty-five thousand nine hundred and twenty in the twenty-four hours. The number is influenced, however, by various circumstances. The child and the female, and perhaps also the aged, breathe more rapidly than the adult male. MM. Hourmann and Dechambre[1] examined two hundred and fifty-five women between the ages of sixty and ninety-six, the average number of whose respirations was 21·79 per minute. According to M. Quetelet,[2] a child breathes in the minute, on the average,—

At birth	44 times.
At 5 years	26 "
From 15 to 20 years	20 "
" 20 to 25 "	18·7 "
" 25 to 30 "	16·0 "
" 30 to 50 "	18.1 "

We find as much variety in the respiration of men as we do in that of horses: whilst some are short, others are long-winded; and this last condition may be improved by appropriate *training*, to which the pedestrian and the prize-fighter, equally with the horse, are subjected for some time before they are called upon to test their powers. In sleep, the respiration is generally deeper, less frequent, and appears to be performed greatly by the intercostals and diaphragm.[3] Motion has also a sensible effect in hurrying the respiration, as well as distension of the stomach by food, certain mental emotions, &c.: it is less in the horizontal than in the sitting posture; and less in the sitting than in the erect. Its condition during disease becomes a subject of interesting study to the physician, and one that has been much facilitated by the acoustic method introduced by Laënnec. To his instrument—the *stethoscope*—allusion has already been made. By it, or by the ear applied to the chest, we are able to hear distinctly the respiratory murmur and its modifications; and thus to judge of the nature of pulmonary affections. But this is a topic that appertains more especially to pathology.

(3.) RESPIRATORY PHENOMENA CONCERNED IN CERTAIN FUNCTIONS.

There are certain respiratory movements, concerned in effecting other functions, that require consideration. Some of these have already been discussed. M. Adelon[4] has classed them into: *First.* Those employed in the *sense of smell*, either for the purpose of conveying the odorous molecules into the nasal fossæ; or to repel them and prevent their ingress. *Secondly.* The inspiratory actions employed in the *digestive function*, as in *sucking*. *Thirdly.* Those connected with muscular motion when forcibly exerted; and particularly with *straining* or the employment of *violent effort*. *Fourthly.* Those concerned in the various *excretions*, either voluntary,—as in *defecation* and *spitting;* or involuntary,—as in *coughing*, *sneezing*, *vomiting*, *accouchement*, &c.; and *lastly*, those that constitute phenomena of *expression*,—as *sighing*, *yawning*, *laughing*,

[1] Archiv. Génér. de Médecine, Nov. 1835.

[2] A Treatise on Man, Chambers's Edinb. translation, p. 71, Edinb., 1842; and Vierordt, art. Respiration, in Wagner's Handwörterbuch der Physiologie, ii. 834, Braunschweig, 1844.

[3] Adelon, Physiologie de l'Homme, iii. 185.

[4] Op. cit., p. 188.

crying, *sobbing*, &c. Some of these, that have already engaged attention, do not demand comment; others are topics of considerable interest, and require investigation.

1. *Straining.*—The state of respiration is much affected during the more active voluntary movements. Muscular exertion of whatever kind, when considerable, is preceded by a long and deep inspiration; the glottis is closed; the diaphragm and respiratory muscles of the chest are contracted, as well as the abdominal muscles which press upon the contents of the abdomen in all directions. Whilst the proper respiratory muscles are exerted, those of the face participate, owing to their association through the medium of particular nerves. By this series of actions, the chest is rendered capacious; and the force that can be developed is augmented, in consequence of the trunk being rendered immovable as regards its individual parts,—thus serving as a fixed point for the muscles that arise from it, so that they are enabled to employ their full effort.[1] The physiological state of muscular action, as connected with the mechanical function of respiration, is happily described by Shakspeare, when he makes the fifth Harry encourage his soldiers at the siege of Harfleur.

> "Stiffen the sinews, summon up the blood;
> Now set the teeth, and stretch the nostrils wide;
> Hold hard the breath and bend up every spirit
> To its full height." KING HENRY V. iii. 1.

In the effort required for effecting the various excretions, a similar action of the respiratory muscles takes place. The organs, from which these excretions have to be removed, are either in the thorax or abdomen; and in all cases have to be compressed by the parietes of those cavities. A full inspiration is first made; the expiratory muscles, with those that close the glottis, are then forcibly and simultaneously contracted, and by this means the thoracic and abdominal viscera are compressed. Some difference, however, exists, according as the viscus to be emptied is seated in the abdomen or thorax. In the evacuation of the fæces, the lungs are first filled with air; and whilst the muscles of the larynx contract to close the glottis, those of the abdomen contract also; and as the lung, in consequence of the included air, resists the ascent of the diaphragm, the compression bears upon the large intestine. The same happens in the excretion of the urine, and in accouchement.

2. *Coughing* and *Sneezing.*—When the organs that have to be cleared are the air-passages,—as in *coughing* to remove mucus from them,—the same action of the muscles of the abdomen is invoked; but the glottis is open to allow the exit of the mucus. In this case, the expiratory muscles contract convulsively and forcibly, so that the air is driven violently from the lungs; and, in its passage, sweeps off the irritating matter, and conveys it out of the body. To aid this, the muscular fibres, at the posterior part of the trachea and larger bronchial tubes, contract, so as to diminish the calibre of these canals; and in this way expectoration is facilitated. The action differs, however, according as the expired air is sent through the nose or mouth; in the

[1] Op. cit., p. 190; and art. Effort, in Dict. de Méd., 2de édit., xi. 197, Paris, 1835.

former case, constituting *sneezing;* in the latter, *coughing.* The former is more violent than the latter, and is involuntary; whilst the latter is not necessarily so. In both cases the movement is excited by some external irritant, applied directly to the mucous membrane of the windpipe or nose; or by some modified action in the very tissue of the part, which acts as an irritating cause. In both cases the air is driven forcibly forwards; and both are accompanied by sounds that cannot be mistaken. In these actions, we have striking exemplifications of the extensive association of muscles, through the medium of nerves, to which we have so often alluded. The pathologist, too, has repeated opportunities for observing the extensive sympathy between distant parts of the frame, as indicated by the actions of sneezing and coughing, especially of the former. If a person be exposed for a short period to the partial and irregular application of cold, so that the organic actions of a part of the body are modified, as where we get the feet wet, or sit in a draught of air, a few minutes is frequently sufficient to exhibit sympathetic irritation in the Schneiderian membrane of the nose, and sneezing. Nor is it necessary, that the organic actions of a distant part shall be modified by the application of cold. We have had the most positive evidence, that if they be irregularly accomplished, even by the application of heat, whilst the rest of the body is receiving none, inflammation of the mucous membrane of the nasal fossæ and fauces may supervene with no less certainty.

3. *Blowing the Nose.*—The substance that has to be excreted by this operation is composed of the nasal mucus, the tears sent down the ductus ad nasum, and the particles deposited on the membrane by the air in its passage through the nasal fossæ. Commonly, these secretions are only present in quantity sufficient to keep the membrane moist, the remainder being evaporated or absorbed. Frequently, however, they exist in such quantity as to fall by their own gravity into the pharynx, where they are sent down into the stomach by deglutition, are thrown out at the mouth, or make their exit at the anterior nares. To prevent this last effect more especially, we have recourse to blowing the nose. This is accomplished by taking in air, and driving it out suddenly and forcibly, closing the mouth at the same time, so that the air may issue by the nasal fossæ and clear them; the nose being compressed so as to make the velocity of the air greater, as well as to express all the mucus that may be forced forwards.

4. *Spitting* differs somewhat according to the part in which the mucus or matter to be ejected is seated. At times, it is exclusively in the mouth; at others, in the back part of the nose, pharynx, or larynx. When the mucus or saliva of the mouth has to be excreted, the muscular parietes of the cavity, as well as the tongue, contract so as to eject it from the mouth; the lips being at times approximated, so as to render the passage narrow, and impel the sputa more strongly forward. The air of expiration may be, at the same time, driven forcibly through the mouth, so as to send the matter to a considerable distance. The practised spitter sometimes astonishes us with the accuracy and power of propulsion of which he is capable. When the matter to be evacuated is in the nose, pharynx, or larynx, it requires to be brought, first of all, into the mouth. If in the posterior nares, the mouth is closed, and the

air is drawn in forcibly through the nose, the pharynx being at the same time constricted so as to prevent the substances from passing down into the œsophagus. The pharynx now contracts from below to above, in an inverse direction to that required in deglutition; and the farther excretion from the mouth is effected in the manner just described.

Where the matters are situate in the air-passages, the action may consist in coughing; or, if higher up, simply in *hawking*. A forcible expiration, unaccompanied by cough, is, indeed, in many cases, sufficient to detach the superfluous mucous secretion from even the bronchial tubes. In hawking, the expired air is sent forcibly forwards, and the parts about the fauces are suddenly contracted so as to diminish the capacity of the tube, and propel the matter onwards. The noise is produced by their discordant vibrations. Both these modes bear the general name of *expectoration*.

When these secretions are swallowed, they are subjected to the digestive process; a part is taken up, and the remainder rejected; so that they belong to the division of *recremento-excrementitial fluids* of some physiologists.

(4.) RESPIRATORY PHENOMENA CONNECTED WITH EXPRESSION.

It remains to speak of the expiratory phenomena that strictly form part of the function of expression, and depict the moral feeling of the individual who gives them utterance.

1. *Sighing* consists of a deep inspiration, by which a large quantity of air is received slowly and gradually into the lungs, to compensate for the deficiency in the due aeration of the blood which precedes it. The most common cause of sighing is mental uneasiness; it also occurs during languor, at the approach of sleep, or immediately after waking. In all these cases, the respiratory efforts are executed more imperfectly than under ordinary circumstances; the blood, consequently, does not circulate through the lungs in due quantity, but accumulates more or less in these organs, and in the right side of the heart; and it is to restore the due balance, that a deep inspiration is now and then established.

2. *Yawning*, *oscitancy*, *oscitation* or *gaping*, is a full, deep, and protracted inspiration, accompanied by a wide separation of the jaws, and followed by a prolonged and sometimes sonorous expiration. It is excited by many of the same causes as sighing. It is not, however, the expression of a depressing passion, but is occasioned by any circumstance that impedes the necessary aeration of the blood; whether it be retardation of the action of the respiratory muscles, or the air being less rich in oxygen. Hence we yawn at the approach of sleep, and immediately after waking. The inspiratory muscles, fatigued from any cause, experience some difficulty in dilating the chest; the lungs are, consequently, not properly traversed by the blood from the right side of the heart; oxygenation is, therefore, not duly effected, and an uneasy sensation is induced; this is put an end to by the action of yawning, which allows the admission of a considerable quantity of air. We yawn at the approach of sleep, because the agents of respiration, becoming gradually more debilitated, require to be now and then ex-

cited to fresh activity, and the blood needs the requisite aeration. Yawning on waking seems to be partly for the purpose of arousing the respiratory muscles to greater activity, the respiration being always slower and deeper during sleep. It is, of course, impossible to explain why the respiratory nerves should be chiefly concerned in these respiratory movements of an expressive character. The fact, however, is certain; and it is remarkably proved by the circumstance, that yawning can be excited by even looking at another affected in this manner; nay, by simply looking at a sketch, and even thinking of the action. The same also applies to sighing and laughing, and especially to the latter.

3. *Pandiculation* or *stretching* is a frequent concomitant of yawning, and appears to be established instinctively to arouse the extensor muscles to a balance of power, when the action of the flexors has been predominant. In sleep, the flexor muscles exercise that preponderance which, in the waking state, is exerted by the extensors. This, in time, is productive of some uneasiness; and hence, occasionally during sleep, but still more at the moment of waking, the extensor muscles are roused to action to restore the equipoise: or, perhaps, as the muscles of the upper extremities, and those engaged directly or indirectly in respiration, are chiefly concerned in the action, it is exerted for the purpose of exciting the respiratory muscles to increased activity.

By Dr. Good,[1] yawning and stretching have been regarded as morbid affections and amongst the signs of debility and lassitude:—"Every one," he remarks, "who resigns himself ingloriously to a life of lassitude and indolence, will be sure to catch these motions as a part of that general idleness which he covets; and, in this manner, a natural and useful action is converted into a morbid habit; and there are loungers to be found in the world, who, though in the prime of life, spend their days as well as their nights in a perpetual routine of these convulsive movements, over which they have no power; who cannot rise from the sofa without stretching their limbs, nor open their mouths to answer a plain question without gaping in one's face. The disease is here idiopathic and chronic; it may perhaps be cured by a permanent exertion of the will, and ridicule or hard labour will generally be found the best remedies for calling the will into action."

4. *Laughing* is a convulsive action of the muscles of respiration and voice, accompanied by a facial expression, which has been explained elsewhere. It consists of a succession of short, sonorous expirations. Air is first inspired so as to fill the lungs. To this succeed short, interrupted expirations, with simultaneous contractions of the muscles of the glottis, so that the aperture is slightly contracted, and the lips assume the tension necessary for the production of sound. The interrupted character of the expirations is caused by convulsive contractions of the diaphragm, which constitute the greater part of the action. In very violent laughter, the respiratory muscles are thrown into such forcible contractions, that the hands are applied to the sides to support them. The convulsive action of the thorax likewise interferes with the circulation through the lungs; the blood, consequently, stagnates

[1] Study of Medicine, class 4, ord. 3, gen. 2, sp. 6.

in the upper part of the body; the face becomes flushed; the sweat trickles down the forehead, and the eyes are suffused with tears; but this is apparently owing in part to mechanical causes; not to the lachrymal gland being excited to unusual action, as in weeping. At times, however, we find the latter cause in operation, also.

5. *Weeping.* The action of weeping is very similar to that of laughing; although the causes are so dissimilar. It consists in an inspiration, followed by a succession of short, sonorous expirations. The facial expression, so diametrically opposite to that of laughter, has been depicted in another place.

Laughter and weeping appear to be characteristic of humanity. Animals shed tears, but the act does not seem to be accompanied by the mental emotion that characterizes crying in the sense in which we employ the term. It has, indeed, been affirmed by Steller,[1] that the *phoca ursina* or *ursine seal;* by Pallas,[2] that the camel; and by Von Humboldt,[3] that a small American monkey, shed tears when labouring under distressing emotions. The last scientific traveller states, that "the countenance of the *titi* of the Orinoco,—*simia sciurea* of Linnæus,—is that of a child; the same expression of innocence; the same smile; the same rapidity in the transition from joy to sorrow. The Indians affirm, that it weeps like man, when it experiences chagrin; and the remark is accurate. The large eyes of the ape are suffused with tears, when it experiences fear or any acute suffering." Shakspeare's description of the weeping of the stag,—

> "That from the hunter's aim had ta'en a hurt,"

is doubtless familiar to most of our readers.

> "The wretched animal heaved forth such groans,
> That their discharge did stretch his leathern coat
> Almost to bursting; and the big, round tears
> Coursed one another down his innocent nose[4]
> In piteous chase; and thus the hairy fool,
> Much marked of the melancholy Jaques,
> Stood on th' extremest verge of the swift brook,
> Augmenting it with tears."
>
> As You Like It, ii. 1.

We have less evidence in favour of the laughter of animals. Le Cat,[5] indeed, asserts, that he saw the chimpanzee both laugh and weep. The orang, carried to Great Britain from Batavia by Dr. Clarke Abel, never laughed; but he was seen occasionally to weep.[6]

6. *Sobbing* still more resembles laughing, except that, like weeping, it is usually indicative of the depressing passions; and generally ac-

[1] Nov. Comm. Academ. Scient. Petropol., ii. 353.

[2] Sammlungen Historisch. Nachricht. über die Mongolischen Völkerschaften, Th. i. 177.

[3] Recueil d'Observations de Zoologie, &c., i. 333.

[4] "The alleged 'big round tears,' which 'course one another down the innocent nose' of the deer, the hare, and other animals, when hotly pursued, are in fact only sebaceous matter, which, under these circumstances, flows in profusion from a collection of follicles in the hollow of the cheek."—Fletcher's Rudiments of Physiology, part ii. *b.* p. 50, Edinb., 1836.

[5] Traité de l'Existence du Fluide des Nerfs, p. 35.

[6] Lawrence, Lectures on Physiology, Zoology, and the Natural History of Man, p. 236, Lond., 1814.

companies weeping. It consists of a convulsive action of the diaphragm; which is alternately raised and depressed, but to a greater extent than in laughing, and with less rapidity. It is susceptible of various degrees, and has the same physical effects upon the circulation as weeping. Dr. Wardrop[1] considers laughter, crying, weeping, sobbing, sighing, &c., as efforts made with a view to effect certain alterations in the quantity of blood in the lungs and heart, when the circulation has been disturbed by mental emotions.

7. *Panting* or *anhelation* consists in a succession of alternate, quick, and short inspirations and expirations. Its physiology, however, does not differ from that of ordinary respiration. The object is, to produce a frequent renewal of air in the lungs, in cases where the circulation is unusually rapid; or where, owing to disease of the thoracic viscera, a more than ordinary supply of fresh air is demanded. We can, hence, understand why dyspnœa should be one of the concomitants of most of the severe diseases of the chest; and why it should occur whenever the air we breathe does not contain a sufficient quantity of oxygen. The panting, produced by running, is owing to the necessity for keeping the chest as immovable as possible, that the whole effort may be exerted on the muscles of locomotion; and thus suspending, for a time, the respiration, or admitting only of its imperfect accomplishment. This induces an accumulation of blood in the lungs and right side of the heart; and panting is the consequence of the augmented action necessary for transmitting it through the vessels.

b. *Chemical Phenomena of Respiration.*

Having studied the mode in which air is received into, and expelled from, the lungs, we have now to inquire into the changes produced on the venous blood—containing the products of the various absorptions—in the lungs; as well as on the air itself. These changes are effected by the function of *sanguification*, *hæmatosis*, *respiration* in the restricted sense in which it is employed by some, *arterialization*, *decarbonization*, *aëration*, *atmospherization*, &c., of the blood. With the ancients this process was but little understood. It was generally believed to be the means of cooling the body; and, in modern times, Helvetius revived the notion, attributing to it the office of refrigerating the blood,—heated by its passage through the long and narrow channels of the circulation,—by the cool air constantly received into the lungs. The reasons, which led to this opinion, were:—that the air, which enters the lungs in a cool state, issues warm; and that the pulmonary veins, which convey the blood from the lungs, are of less dimension than the pulmonary artery, which conveys it to them. From this it was concluded, that the blood, during its progress through the lungs, must lose somewhat of its volume, or be condensed by refrigeration. The warmth of the expired air can, however, be readily accounted for; and it is not true that the pulmonary veins are smaller than the pulmonary artery. The reverse is the fact; and it is obvious, that the doctrine of Helvetius does not explain how we can exist in a tempera-

[1] On the Nature and Treatment of Diseases of the Heart, part i. p. 62, Lond., 1837.

ture superior to our own; which, in his hypothesis, ought to be impracticable.[1]

Another theory, which prevailed for some time, was;—that during inspiration the vessels of the lungs are deployed or unfolded, as it were, and that thus the passage of the blood from the right side of the heart to the left, through the lungs, is facilitated. Its progress was, indeed, conceived to be impossible during expiration, in consequence of the considerable flexures of the pulmonary vessels. The discovery of the circulation of the blood gave rise to this theory; and Haller[2] attaches importance to it, when taken in connexion with the changes effected upon the blood in the vessels. It is incorrect, however, to suppose, that the circulation of the blood through the lungs is mechanically interrupted, when respiration is arrested. The experiments of Drs. Williams[3] and Kay[4] would seem to show, that the interruption is mainly ascribable to the non-conversion of venous into arterial blood, and to the non-adaptation of the radicles of the pulmonary veins for any thing but arterial blood, owing to which causes stagnation of blood supervenes in the pulmonary radicles. Numerous other objections might be made to this view. In the first place, it supposes, that the lungs are emptied at each expiration; and, again, if a simple deploying or unfolding of the vessels were all that is required, any gas ought to be sufficient for respiration,—which is not the fact.

In these different theories, the principal object of respiration is overlooked—the conversion of the venous blood, conveyed to the lungs by the pulmonary artery, into arterial blood. This is effected by the contact of the inspired air with the venous blood; in which they both lose certain elements, and gain others. Most physiologists have considered that the whole function of hæmatosis is effected in the lungs. M. Chaussier,[5] however, has presumed, that some kind of elaboration is effected on the air, in passing through the cavities of the nose and mouth, and the different bronchial ramifications, by being agitated with the bronchial mucus; similar to what he conceives is effected by the mucus on the aliment in its passage from the mouth to the stomach; but his view is conjectural in both one case and the other. M. Legallois,[6] again, thought, that hæmatosis commences at the part, where the chyle and lymph are mixed with the venous blood, or in the subclavian vein. This admixture, he conceives, occurs more or less immediately; is aided in the heart, and the conversion is completed in the lungs. To this belief he was led by the circumstance, that when the blood quits the lungs it is manifestly arterial; and he thought, that what the products of absorption lose or gain in the lungs is too inconsiderable to account for the important and extensive change; and that therefore it must have commenced previously. Facts, however, are not exactly in accordance with the view of Legallois. They seem to show, that the blood of the pulmonary artery is

[1] Adelon, Physiologie de l'Homme, edit. cit., iii. 201.

[2] Element. Physiol., lib. viii. sect. iv., Lausann., 1766.

[3] Edinburgh Medical and Surgical Journal, vol. lxxvii., 1823.

[4] Edinburgh Med. and Surg. Journal, vol. xxix.; and Physiology and Pathology, &c., of Asphyxia, Lond., 1834.

[5] Adelon, Physiologie de l'Homme, iii. 205.

[6] Annales de Chimie, iv. 115.

analogous to that of the subclavian vein; and hence it is probable, that there is no other action exerted upon the fluid in this part of the venous system, than a more intimate admixture of the venous blood with the chyle and lymph in their passage through the heart.

The changes, wrought on the air by respiration, are considerable. It is immediately deprived of a portion of both of its main constituents—oxygen and nitrogen; and it always contains, when expired, a quantity of carbonic acid greater than it had when received into the lungs, along with an aqueous and albuminous exhalation to a considerable amount.

Oxygen is consumed in the respiration of all animals, from the largest quadruped to the most insignificant insect; and if we examine the expired air, the deficiency is manifest. Many attempts have been made to estimate the precise quantity consumed during respiration; but the results vary essentially from each other; partly owing to the fact, that the amount consumed by the same animal differs in different circumstances. Menzies[1] was probably the first that attempted to ascertain the quantity consumed by man in a day. According to him, 36 cubic inches are expended in a minute; consequently, 51,840 in the twenty-four hours, equal to 17,496 grains. Lavoisier[2] makes it 46,048 cubic inches, or 15,541 grains. This was the result of his earlier experiments, and, in his last, which he was executing at the time when he fell a victim to the tyranny of Robespierre, he made it 15592·5 grains; corresponding greatly with the results of his earlier observations. The experiments of Sir Humphry Davy[3] coincide greatly with those of Lavoisier. He found the quantity consumed in a minute to be 31·6 cubic inches; making 45,504 cubic inches, or 15,337 grains in twenty-four hours. The results obtained by Messrs. Allen and Pepys[4] make it much less. They consider the average consumption to be, in the twenty-four hours, under ordinary circumstances, 39,534 cubic inches, equal to 13,343 grains.

If we regard the experiments of Lavoisier and Davy, between which there is the greatest coincidence, to be an approximation to the truth, it will follow, that, in a day, a man consumes rather more than 25 cubic feet of oxygen; and as the oxygen amounts to only about one-fifth of the respired air, he must render 125 cubic feet of air unfit for supporting combustion and respiration.

The experiments of Crawford, Jurine, Lavoisier and Séguin, Prout, Fyfe, and Edwards,[5] have proved, that the quantity of oxygen consumed varies according to the condition of the functions and the system generally. Séguin[6] found, that muscular exertion increases it nearly fourfold. Dr. Prout,[7] who gave much attention to the subject, was induced to conclude, from his experiments, that moderate exercise increases it; but if the exercise be continued so as to induce fatigue, a

[1] Dissertation on Respiration, p. 21, Edin., 1796.
[2] Mémoir. de l'Académ. des Sciences, 1789, 1790.
[3] Researches, &c., p. 431.
[4] Philos. Transact. for 1808.
[5] De l'Influence des Agens Physiques sur la Vie, p. 410, Paris, 1824; or Hodgkin and Fisher's translation.
[6] Mém. de l'Académ. des Sciences, 1789 and 1790.
[7] Annals of Philos., ii. 330, iv. 331, and xiii 269.

diminished consumption takes place. The exhilarating passions appeared to increase the quantity; whilst the depressing passions and sleep, the use of alcohol and tea, diminished it. He discovered, that the quantity of oxygen consumed is not uniformly the same during the twenty-four hours. Its maximum occurred between 10 A.M. and 2 P.M., or generally between 11 A.M. and 1 P.M.: its minimum commenced about 8½ P.M., and it continued nearly uniform till about 3½ A.M. Dr. Fyfe[1] found, that the quantity was diminished by a course of nitric acid, by a vegetable diet, and by affecting the system with mercury. Temperature has an influence. Dr. Crawford[2] found, that a Guinea-pig, confined in air at the temperature of 55°, consumed double the quantity which it did in air at 104°. He also observed, in such cases, that venous blood, when the body was exposed to a high temperature, had not its usual dark colour; but, by its florid hue, indicated that the full change had not taken place in its constitution in the course of circulation. The same fact is mentioned by a recent observer, who affirms, that if, when an animal is near dying from the effect of heat, an artery be opened, its blood is as black as that of a vein, and does not become bright by exposure.

We may thus understand the great lassitude and yawning, induced by the hot weather of summer; and the languor and listlessness which are so characteristic of those who have long resided in torrid climes. Dr. Prout conceives, that the presence or absence of the sun alone regulates the variation in the consumption of oxygen which he has described; but the deduction of Dr. Fleming[3] appears to be more legitimate,—that it keeps pace with the degree of muscular action, and is dependent upon it. Consequently, a state of increased consumption is always followed by an equally great decrease, in the same manner as activity is followed by fatigue.

The disagreement of experimenters, as respects the removal of *nitrogen* or *azote* from the air, during respiration, is still greater than in the case of oxygen. Priestley, Davy, Von Humboldt, Henderson, Cuvier, and Pfaff, found a less quantity exhaled than was inspired. Spallanzani, Lavoisier and Séguin, Vauquelin, Allen and Pepys, Ellis, Thomson, Valentin and Brunner, and Dalton, inferred that neither absorption nor exhalation takes place,—the quantity of that gas, in their opinion, undergoing no change during its passage through the air-cells of the lungs; whilst Jurine, Nysten, Berthollet, and Dulong and Despretz, on the contrary, found an increase in the bulk of the nitrogen. In this uncertainty, most physiologists have been of opinion that the nitrogen is entirely passive in the function. The facts, ascertained by M. W. F. Edwards,[4] of Paris, shed considerable light on the causes of this discrepancy amongst observers. He has satisfactorily shown that, in the respiration of the same animal, the quantity of nitrogen may be, at one time, augmented; at another, diminished; and, at a third, wholly unchanged. These phenomena he has traced to the influence of the seasons, and he suspects that other causes have a share in their production. In nearly all the lower animals that were the subjects of expe-

[1] Annals of Philos., iv. 334, and Bostock's Physiol., i. 350.
[2] Op. cit., p. 387.
[3] Philosophy of Zoology, i. 355, Edinburgh, 1822.
[4] Op. cit., p. 462.

riment, an augmentation of nitrogen was observable during summer. Sometimes, it was so slight that it might be disregarded; but, in numerous instances, it was so great as to place the fact beyond the possibility of doubt; and, on some occasions, it almost equalled the whole bulk of the animal. Such were the results of his observations until the close of October, when he noticed a sensible diminution in the nitrogen of the inspired air, and the same continued throughout the whole of winter and beginning of spring. M. Edwards considers it probable, that, in all cases, both exhalation and absorption of nitrogen are going on; that they are frequently accurately balanced, so as to exhibit neither excess nor deficiency of nitrogen in the expired air; whilst, in other cases, depending, as it would appear, chiefly upon temperature, either the absorption or the exhalation is in excess, producing a corresponding effect upon the composition of the air of expiration. MM. Regnault and Reiset,[1] in their experiments on animals, always observed an exhalation of nitrogen; the proportion of which varied—as in the case of carbonic acid formed—with the nature of the food.

Whilst the respired air has lost its oxygenous portion, it has received, as we have remarked, an accession of *carbonic acid*, and, likewise, a quantity of watery vapour. If we breathe through a tube, one end of which is inserted into a vessel of lime-water, the fluid soon becomes milky, owing to the formation of carbonate of lime, which is insoluble in water. Carbonic acid must, consequently, have been given off from the lungs. In the case of this gas, again, it has been attempted to compute the quantity formed in the day. Jurine conceived, that the amount, in air once respired in natural respiration, is in the large proportion of $\frac{1}{10}$th or $\frac{1}{12}$th; Menzies, that it is $\frac{1}{20}$th; and, from his estimate of the total quantity of air respired in the twenty-four hours, he deduced the amount of carbonic acid formed to be 51840 cubic inches, equal to 24105·6 grains. MM. Lavoisier and Séguin,[2] in their first experiments, valued it at 17720·89 grains; but in the next year they reduced their estimate more than one-half;—to 8450.20 grains; and, in Lavoisier's last experiment, it was farther reduced to 7550·4 grains. Sir Humphry Davy's estimate nearly corresponds with that of the first experiment of MM. Lavoisier and Séguin,—17811·36 grains; and Messrs. Allen and Pepys accord pretty nearly with him. These gentlemen found, that air, when inspired, issued, on the succeeding expiration, charged with from 8 to 6 per cent. of carbonic acid; but this estimate greatly exceeds that of Dr. Apjohn,[3] of Dublin, who, in his experiments, found the expired air to contain only 3·6 per cent. The experiments and observations of Messrs. Crawford, Prout, Edwards, and others, to which we have referred—as regards the consumption of oxygen, under various circumstances—apply equally to the quantity of carbonic acid formed, which always bears a pretty close proportion to the oxygen consumed. These experiments also account, in some degree, for the discrepancy in the statements of individuals on this subject.

The observations of Vierordt,[4] at various temperatures between 38°

[1] Comptes Rendus, Paris, 1848.

[2] Mémoir. de l'Académ. des Sciences, p. 609, Paris, 1790.

[3] Edinb. Med. and Surg. Journal, Jan., 1831.

[4] Lehrbuch der Physiologischen Chemie, iii. 386, Leipzig, 1852; or Amer. edit. of Dr. Day's translation, by Dr. Robert E. Rogers, ii. 443, Philad., 1855.

and 75° Fahr., showed, that a rise equal to 10° caused a diminution of about two cubic inches in the quantity of carbonic acid exhaled per minute. Letellier,[1] too, found, by experiments on animals at much higher and lower temperatures than those, that the higher the temperature, as far as 104°, the less was the amount of carbonic acid exhaled, whilst the nearer it approached zero the greater was the amount of carbonic acid given of.

The experiments of Mr. Coathupe,[2] which were carefully conducted, make the amount of carbonic acid, generated in the 24 hours, about 17856 cubic inches, that is 2·616 grains or 5½ ounces of solid carbon. Liebig found the proportion of carbon expired by himself to be 8½ ounces daily; by a soldier, 13½ ounces; by prisoners in close confinement, 7 ounces; and by a boy who took considerable exercise, 9 ounces.[3] Subsequently, farther experiments were made on the subject by competent observers. Professor Scharling,[4] of Copenhagen, found, that, at the age of 35, he exhaled 7·7 ounces avoirdupois of carbon in the twenty-four hours—seven of which were passed in sleep. A soldier, 28 years of age, exhaled 8·15 ounces; a lad of 16, 7·9 ounces; a young woman, aged 19, 5·83 ounces; a boy, 9½ years old, 3·069 ounces; and a girl, 10 years old, 4·42 ounces. In the last two, the time spent in sleep was 9 hours. These amounts, however, were exhaled both from the lungs and cutaneous surface. He constructed an air-tight chamber, of dimensions sufficient to permit him to remain in it for some time without inconvenience. This was connected with an apparatus by which the air was constantly renewed, and the air removed was carefully analyzed, in order to determine the quantity of carbonic acid contained in it. Of the 7·7 ounces exhaled by himself in the twenty-four hours, we may perhaps estimate the amount from the lungs at 5·5 ounces. He infers, from all his experiments, that males exhale more carbonic acid than females; and children comparatively more than adults.

MM. Andral and Gavarret undertook a series of interesting experiments on the subject. Their first object was to ascertain the modifying influence of age, sex, and constitution on the quantity of carbonic acid exhaled from the lungs. To determine this, their observations were made under circumstances as uniform as possible; and each experiment was repeated several times on the same subject. The apparatus employed was so devised as to enable the respirations to be freely performed; no portion of the expired air was again inspired; and the greatest care was taken to analyze the expired air with accuracy. The general results obtained by these observers were as follows:—1. The quantity of carbonic acid exhaled by the lungs in a given time varies according to age, sex, and constitution. 2. In both male and female, the quantity undergoes modification, according to the ages of the individuals experimented upon, quite independently of their weights. 3. In all periods of life, there is a difference between the male and female

[1] Annales de Chimie et de Physique, 1845.
[2] Philosophical Magazine, June, 1839.
[3] Graham's Elements of Chemistry, Amer. edit., p. 686, Philad., 1843.
[4] Annales des Sciences Naturelles, Février, 1843; cited in Brit. and For. Med. Rev. for July, 1843, p. 285.

in the amount of carbonic acid exhaled in a given time: *cæteris paribus*, man exhales a much larger quantity than woman. Between the ages of 16 and 40, the former exhales nearly twice as much as the latter. 4. In man, the quantity exhaled goes on regularly increasing from 8 to 30 years of age; and a remarkable augmentation takes place at puberty. After 30, it begins to decrease; and the decrease continues becoming more and more marked as the individual approaches nearer and nearer extreme old age; so that, at this last period, it returns to the standard at which it was about the age of ten. 5. In woman the exhalation augments up to the period of puberty, according to the same law as in man; the increase then suddenly ceases, and the quantity continues at this low standard, with little variation so long as the catamenia appear regularly; but as soon as they cease, the exhalation of carbonic acid from the lungs undergoes a considerable augmentation, after which it decreases as in man, according to the advance of age. 6. During pregnancy, the amount of carbonic acid exhaled is raised temporarily to the standard which it attains after the cessation of the catamenia. 7. In both sexes, and at all ages, the quantity of carbonic acid exhaled by the lungs is greater in proportion to the strength of the constitution, and the developement of the muscular system.

The following table exhibits the amount of solid carbon calculated to be exhaled in one hour at different ages;—the *gramme* is equal to about 15½ grains.

Male.		Female.		
8 years.	5 grammes.	8 years.	5 grammes.	The same standard continues in women during the whole of the menstrual period: but if the catamenia be temporarily suppressed, or pregnancy occur, it rises to the standard it attains after their entire cessation, namely, 8·4 grammes.
15	8·7	12–38	6·4	
16	10·8	38–50	8·4	
18–20	11·4	50–60	7·3	
20–30	12·2	60–80	6·8	
30–40	12·2	82	6·0	
40–60	10·1			
60–80	9·2			
102	5·9			

These numbers express the averages,—the maximum amount being often considerably greater. In a young man of athletic system, and sound constitution, the quantity of carbonic acid exhaled in an hour was 14·1 grammes; in a man of 60, equally vigorous for his age, 13·6 grammes; and in one of 63, 12·4 grammes. An old man, of 92, of a remarkable degree of energy, and who had possessed unusual vigour in his youth, was found to exhale 8·8 grammes per hour; whilst the same amount appeared to be the ordinary standard in a man of 45; who, unlike the last, had a feeble system, although in equally good health. How far these variations were connected with differences in the capacity of the chest, and with the number of the respiratory movements, MM. Andral and Gavarret proposed to investigate subsequently. This they have not done.

The following table, by Dr. John Reid,[1] of the quantity of carbonic

[1] Art. Respiration, Cyclopædia of Anat. and Physiol., Pt. xxxii. p. 345, Lond., Aug. 1848.

acid gas in 100 parts of the expired air estimated by volume gives the result obtained by recent experimenters.

	Average.	Maximum.	Minimum.	Difference between Maximum and Minimum.
Prout . . .	3·45	4·10	3·30	.80
Coathupe . . .	4·02	7·98	1·91	6·07
Brunner and Valentin	4·380	5·495	3·299	2·196
Vierordt . . .	4·334	6·220	3·358	2·86
Thomson . . .	4·16	7·16	1·71	5·45

It has been a question amongst physiologists, whether the quantity of carbonic acid given out is equal in bulk to the oxygen taken in. In Dr. Priestley's experiments,[1] the latter had the preponderance. Menzies and Crawford found them to be equal. MM. Lavoisier and Séguin supposed the oxygen, consumed in the twenty-four hours, to be 15661·66 grains; whilst the oxygen, required for the formation of the carbonic acid given out, was no more than 12924 grains; and Sir Humphry Davy found the oxygen consumed in the same time to be 15337 grains, whilst the carbonic acid produced was 17811·36 grains; which would contain 12824·18 grains of oxygen. The experiments of Messrs. Allen and Pepys seem, however, to show that the oxygen which disappears is replaced by an equal volume of carbonic acid; and hence it was supposed that the whole of it must have been employed in the formation of this acid. They, consequently, accord with Menzies and Crawford; and the view is embraced by Dalton, Prout, Ellis, Henry, and other distinguished individuals. On the other hand, the view of those, who consider that the quantity of carbonic acid produced is less than that of the oxygen which has disappeared, is embraced by Dr. Thomson, and by MM. Dulong and Despretz. In the carnivorous animal, they found the difference as much as one-third; in the herbivorous, on the average, only one-tenth. The experiments of M. Edwards have shown, that here, also, the discordance has not depended so much upon the different methods and skill of the operators, as upon a variation in the results arising from other causes; and he concludes, that the proportion of oxygen consumed to that employed in the production of carbonic acid varies from more than one-third of the volume of carbonic acid to almost nothing; that the variation depends upon the particular animal species subjected to experiment, its age, or some peculiarity of constitution, and that it differs considerably in the same individual at different times.

According to the law of diffusion of gases, the carbonic acid given off from the blood will, of itself, independently of the movements of respiration, have a tendency to quit the lungs by diffusing itself in the external air in which it is in less proportion; and the oxygen of the bronchial tubes and external air will have a tendency to pass towards the air-cells in which its proportion is less than in the air of the tubes and the external air. Were this not the case, the air in the air-cells would be highly charged with carbonic acid, and could not fail

[1] Experiments, &c., on Different Kinds of Air, vol. iii., 3d edit., Lond., 1781.

to act injuriously, inasmuch as the respiratory movements, even when aided by the resiliency of the pulmonary tissue, can never empty the air-cells; and hence there is always—as has been shown—a quantity of *reserve* and *residual* air in the cells.[1]

Interesting experiments by Valentin[2] and Brunner, made on a large scale, seemed to demonstrate, that the chemical changes in respiration are a good deal owing to the simple diffusion of gases taking place between those of the atmosphere and of the blood. The volumes of oxygen absorbed and of carbonic acid exhaled from the blood may be, according to them, determined by the established laws of the diffusion of gases, so that, for one volume of carbonic acid exhaled, 1·17421 volume of oxygen is absorbed,—these numbers representing the proportionate diffusion-volumes of the two gases, calculated according to the law that they are inversely as the square roots of their specific gravities,—or, according to weight, one part of carbonic acid to 0·85163 of oxygen. One part by weight of carbonic acid contains 0·72727 of oxygen; consequently for each part of carbonic acid discharged in respiration, there is an excess of 0·12436 of oxygen, which is disposed of otherwise than in forming the carbonic acid thrown off from the lungs,—or, by volumes, for each one of carbonic acid there is an excess of 0·17421 of oxygen. Hence if it be known how much carbonic acid has been exhaled from the lungs in a given time, we can calculate the amount of oxygen absorbed in the same time. Valentin and Brunner satisfied themselves, that in a medium temperature and atmospheric pressure, each of them, on an average of six experiments, breathed 562·929 *litres* of air in the hour, and, in the same time, expired 635·8565 grains of carbonic acid, containing 173·414 grains of carbon. From this and their respective diffusion-volumes, the hourly consumption of oxygen was calculated at 541·5 grains;—the results obtained by these gentlemen according greatly with those of MM. Andral and Gavarret.

A series of apparently carefully conducted experiments in regard to the changes produced in the air by respiration was performed by MM. Regnault and Reiset.[3] The following are the results of one on a young dog, which was confined in an appropriate apparatus for twenty-four hours and a half.

Oxygen consumed, ...	182·288	grammes.
Carbonic acid produced, ...	185·961	"
Oxygen contained in the carbonic acid, . . .	135·244	"
Nitrogen given off, ...	0·1820	"

Representing the quantity of oxygen consumed at 100, the results would be as follows:—

Oxygen consumed, ...	100
Oxygen in the carbonic acid, ...	74·191
Oxygen otherwise disposed of, ...	25·809
Nitrogen disengaged, ...	0·0549
Average quantity of oxygen consumed in an hour, .	7·44

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[1] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 131, Philad. 1853.
[2] Lehrbuch der Physiologie des Menschen, i. 547.
[3] Comptes Rendus, Paris, 1848.

These experiments are not confirmatory, however, of the views of Valentin and Brunner, in regard to the exchanged oxygen and carbonic acid in respiration, being in the proportion to each other as their diffusion-volumes. Fresh observations are, indeed, needed on this subject. In the meantime it has been well remarked by Messrs. Kirkes and Paget,[1] that the conditions of the gases, engaged in respiration, are not those in which the law of diffusion would exactly hold. The law requires, that both gases should be free and under equal pressure; whilst in the actual case, the gas in the blood is dissolved under pressure, and separated by a membrane from that with which it has to be diffused.

In their experiments on animals, MM. Regnault and Reiset found that the nature of the diet influences the relative amount of oxygen absorbed, and of carbonic acid given out. When animals were fed on flesh, they absorbed much more oxygen in proportion. In the case of a dog, confined exclusively to this kind of aliment, the proportion of oxygen absorbed to 100 parts of carbonic acid exhaled was 134·3, much more than that which the law of diffusion of gases would indicate; whilst in that of a rabbit, fed wholly on vegetable food, the proportion was as 100 to 109·34, or less. The difference between the relative proportions of surplus oxygen in the same animal, under these different circumstances, was as high as 62 to 104. The same experimenters found that, when an animal was kept fasting, the relation between the quantity of oxygen absorbed, and of carbonic acid exhaled, is nearly the same as when it is fed on flesh;—"the reason evidently being," observes a recent writer,[2] "that in the former case the animal's respiration is kept up at the expense of the constituents of its own body, which correspond with animal food in their composition." It must be borne in mind, however, that in such circumstances the fat would probably be most largely taken up; and it corresponds in composition with vegetable food.

It would appear, then, that the whole of the oxygen, which respiration abstracts from the air, is by no means accounted for by the quantity of carbonic acid formed; and that, consequently, a portion of it disappears altogether. It has been supposed by some, that a part of the watery vapour, given off during expiration is occasioned by the union of a portion of the oxygen of the air with hydrogen from the blood in the lungs; but the view is conjectural. This subject, with the quantity of vapour combined with the expired air, will be a matter of inquiry under the head of SECRETION.[3]

The air likewise loses, during inspiration, certain foreign matters diffused in it. In this way, it has been attempted to convey medicines into the system. If air, charged with odorous particles,—as with those of turpentine,—be breathed for a short time, their presence in the urine can be detected; and it is probably in this manner, that miasmata

[1] Op. cit., p. 137.

[2] Carpenter's Principles of Physiology, 4th Amer. edit., p. 304, Philad., 1855.

[3] See on the whole of this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., pt. xxxii. p. 346, Lond., Aug., 1848; and Vierordt, art. Respiration, Wagner's Handwörterbuch der Physiologie, 12te Lieferung, s. 828, Braunschweig, 1845.

produce their effects on the frame. Anæsthetic agents act in the same way; and all pass immediately through the coats of the pulmonary veins by imbibition, and thus, speedily affect the system. The changes, produced in the air during respiration, are easily shown, by placing an animal under a bell-glass, until it dies. On examining the air, it will be found to have lost a portion of its oxygen and nitrogen, and to contain carbonic acid and aqueous vapour. The expired air has always, even in greatly varying temperatures of the atmosphere, a temperature of from 97°·25 to 99°·5 Fahr.,—most commonly the latter.

It may now be inquired, whether the changes produced in the respired air are connected with those effected on the blood in the lungs. In its progress through the lungs, this fluid has been changed from *venous* into *arterial*. It has become of a florid red colour; of a stronger odour; of a higher temperature by from one to four degrees, according to some,[1] but others have perceived no difference, whilst others, again, have found it of lower temperature;[2]—Prof. Bernard has, indeed, established this unanswerably.[3] It is of less specific gravity, in the ratio of 1053 to 1050 on the average, according to Dr. John Davy;[4] and it coagulates more speedily, according to most observers; but Mr. Thackrah[5] observed the contrary. That this conversion is owing to the contact of air in the lungs we have many proofs. Lower[6] was one of the first, who clearly pointed out, that the change of colour occurs in the capillaries of the lungs. Prior to his time, the most confused notions had prevailed on the subject, and the most visionary hypotheses been indulged. On opening the thorax of a living animal, he observed the precise point of the circulation at which the change of colour takes place; and showed, that it is not in the heart, since the blood, when it leaves the right ventricle, continues to be purple. He then kept the lungs artificially distended, first with a regular supply of fresh air, and afterwards with the same portion of air without renewing it. In the former case, the blood experienced the usual change of colour. In the latter, it was returned to the left side of the heart unaltered.

Experiments, more or less resembling those of Lower, have been performed by Goodwyn,[7] Cigna, Bichat,[8] Wilson Philip, and numerous others,—and with similar results.

The direct experiments of Dr. Priestley[9] more clearly showed, that

[1] Magendie, Précis de Physiologie, ii. 343; Dr. J. Davy, in Philos. Transact. for 1814; Metcalfe on Caloric, ii. 548, Lond., 1843; and Becquerel and Breschet, Annales des Sciences Naturelles, 2de série, vii. 94, Paris, 1837.

[2] Wagner's Elements of Physiology, by R. Willis, § 180, Lond., 1842; and Simon's Animal Chemistry, vol. i. p. 193, Lond., 1845.

[3] Notes of M. Bernard's Lectures on the Blood: by Walter F. Atlee, M. D., p. 140, Philad., 1854; and Gavarret, De la Chaleur Produite par les Etres Vivants, p. 110, Paris, 1855.

[4] Physiological and Anatomical Researches, American Med. Library edit., p. 16, Philad., 1840.

[5] Inquiry into the Nature and Properties of the Blood, p. 42, Lond., 1819.

[6] Tractatus de Corde, &c., c. iii., Amstelod., 1761.

[7] The Connection of Life with Respiration, &c., Lond., 1788.

[8] Recherches Physiol. sur la Vie et la Mort, 3ème édit., p. 238, Paris, 1805.

[9] Experiments, &c., on Different Kinds of Air, &c., Lond., 1781.

the change effected on the blood was to be ascribed to the air. He found, that a clot of venous blood, confined in a small quantity of air, assumed a scarlet colour, and that the air experienced the same change as from respiration. He afterwards examined the effects produced on the blood by the gaseous elements of the atmosphere separately, as well as by the other gaseous fluids that had been discovered in his time. The clot was reddened more rapidly by oxygen than by the air of the atmosphere, whilst it was reduced to a dark purple by nitrogen, hydrogen, and carbonic acid.

Since Dr. Priestley's time, the effect of different gases on the colour of venous blood has been investigated by numerous observers. The following is the result of their observations, as given by M. Thénard.[1] It must be remarked, however, that all the experiments were made on blood out of the body; and it by no means follows, that precisely the same changes would be accomplished if it were circulating in the vessels.

Gas.	Colour.	Remarks.
Oxygen	Rose red.	The blood employed had been beaten, and, consequently, deprived of its fibrin.
Atmospheric air . . .	Do.	
Ammonia . . .	Cherry red.	
Gaseous oxide of carbon .	Slightly violet red.	
Deutoxide of azote . .	Do.	
Carburetted hydrogen .	Do.	
Azote	Brown red.	
Carbonic acid . . .	Do.	
Hydrogen . . .	Do.[2]	
Protoxide of azote . .	Do.	
Arseniuretted hydrogen . Sulphuretted hydrogen .	Deep violet, passing gradually to a greenish brown.	
Chlorohydric acid gas .	Maroon brown.	These three gases coagulated the blood at the same time.
Sulphurous acid gas .	Black brown.	
Chlorine	Blackish brown, passing by degress to a yellowish white.	

It is sufficiently manifest, then, from the disappearance of a part of the oxygen from the inspired air, and from the effects of that gas on venous blood out of the body, that it plays an essential part in the function of sanguification. But we have seen, that the expired air contains an unusual proportion of carbonic acid. Hence carbon, either in its simple state or united with oxygen, must have been given off from the blood in the vessels of the lungs.

To account for these changes on chemical principles has been a great object with chemical physiologists at all times. At an early period, the conversion of venous into arterial blood was supposed to be a kind of combustion; and, according to the Stahlian notion of combustion then prevalent, it was presumed to consist in the disengagement of phlogiston; in other words, the abstraction or addition of a portion of phlogiston made the blood, it was conceived, arterial or venous; and

[1] Traité de Chimie, &c., 5e édit., Paris, 1827.

[2] Müller says he agitated blood with hydrogen, but could perceive no change of colour. Handbuch, u. s. w., Baly's translation, p. 322, Lond., 1838.

its removal was looked upon as the principal use of respiration. This hypothesis was modified by M. Lavoisier, who proposed one of the chemical views to be now mentioned.

Two chief chemical theories have been framed to explain the mode in which carbon is given off. The first is that of Black,[1] Priestley,[2] Lavoisier,[3] Crawford;[4] and others;[5]—that the oxygen of the inspired air attracts carbon from venous blood, and the carbonic acid is generated by their union. The second, which has been supported by La Grange,[6] Hassenfratz,[7] Edwards,[8] Müller,[9] Bischoff, Magnus, and others, —that the carbonic acid is generated in the course of the circulation, and is given off from the venous blood in the lungs, whilst oxygen gas is absorbed. The former of these views is still maintained by many chemical physiologists. It is conceived, that the oxygen, derived from the air unites with certain parts of the venous blood,—the carbon and hydrogen,—owing to which union, carbonic acid and water are found in the expired air; the venous blood, thus depurated of its carbon and hydrogen, becomes arterialized; and, in consequence of these various combinations, heat enough is disengaged to keep the body always at the due temperature. According to this theory, respiration is assimilated to combustion. The resemblance, indeed, between the two processes is striking. The presence of air is absolutely necessary for respiration; in every variety the air is robbed of a portion of its oxygen; hence a fresh supply is continually needed; and respiration is always arrested before the whole of the oxygen of the air is exhausted; and this partly on account of the residuary nitrogen and carbonic acid gas given off during expiration. Lastly, it can be continued much longer when an animal is confined in pure oxygen than in atmospheric air. All these circumstances likewise occur in combustion. Every kind requires the presence of air. A part of the oxygen is consumed; and, unless the air is renewed, combustion is impossible. It is arrested, too, before the whole of the oxygen is consumed, owing to the residuary nitrogen, and carbonic acid formed; and it can be longer maintained in pure oxygen than in atmospheric air. Moreover, when air has been respired, it becomes unfit for combustion. Again, the oxygen of the air, in which combustion is taking place, combines with the carbon and hydrogen of the burning body; hence the formation of carbonic acid and water; and, as in this combination, the oxygen passes from the state of a rare gas, or one containing a considerable quantity of caloric between its molecules, to that of a much denser, and even of a liquid, the whole of the caloric, which the oxygen contained in its former state, can no longer be held in the latter, and is accordingly disengaged; hence the increased temperature. In like manner, in respiration, the oxygen of the inspired air, it is conceived, combines with the carbon and hydrogen of the venous blood, giving

[1] Lectures on the Elements of Chemistry, by Robison, ii. 87, Edinb., 1803.
[2] Philosoph. Transact. for 1776, p. 147.
[3] Mém. de l'Acad. des Sciences, pour 1777, p. 185.
[4] On Animal Heat, 2d edit., Lond., 1788.
[5] Metcalfe, op. cit.
[6] Annales de Chimie, ix. 269.
[7] Ibid., ix. 265.
[8] De l'Influence des Agens Physiques, &c., p. 411, Paris, 1823; or Hodgkin and Fisher's translation.
[9] Physiology, by Baly, p. 537.

rise to the formation of carbonic acid and water; and, as in these combinations, the oxygen passes from the state of a rare to that of a denser gas, or of a liquid, there is a considerable disengagement of caloric, which becomes the source of the high temperature maintained by the human body. M. Thénard[1] admits a modification of this view,—sanguification being owing, he conceives, to the combustion of the carbonaceous parts of the venous blood, and probably of its colouring matter, by the oxygen of the air.

This chemical theory, which originated chiefly with Lavoisier, and La Place and Séguin, was adopted by many physiologists with but little modification. Mr. Ellis, indeed, imagined, that the carbon is separated from the venous blood by a secretory process; and that then, coming into direct contact with oxygen, it is converted into carbonic acid. The circumstance that led him to this opinion was his disbelief in the possibility of oxygen being able to act upon the blood through the animal membrane or coat of the vessel in which it is confined. It is obvious, however, that to reach the blood circulating in the lungs, the oxygen must, in all cases, pass through the coats of the pulmonary vessels. These coats, indeed, offer little or no obstacle, and, consequently, there is no necessity for the vital or secretory action suggested by Mr. Ellis. Besides, Priestley and Hassenfratz exposed venous blood to atmospheric air and oxygen in a bladder, and in all cases, the parts of the blood, in contact with the gases, became of a florid colour. The experiments of Drs. Faust, Mitchell, and others (p. 68), are, in this respect, pregnant with interest. They prove the great facility with which the tissues are penetrated by gases, and confirm the facts developed by the experiments of Priestley, Hassenfratz, and others.

The second theory,—that the carbonic acid is generated in the course of the circulation,—was proposed by M. La Grange, in consequence of the objection he saw to the former hypothesis—that the lung ought to be consumed by the perpetual disengagement of caloric within it; or, if not so, that its temperature ought to be much superior to that of other parts. He accordingly suggested, that, in the lungs, the oxygen is simply absorbed, passes into the venous blood, circulates with it, and unites, in its course, with the carbon and hydrogen, so as to form carbonic acid and water, which circulate with the blood, and are finally exhaled from the lungs.

The ingenious and apparently accurate experiments of M. Edwards[2] proved convincingly, not only that oxygen is absorbed by the pulmonary vessels, but that carbonic acid is exhaled from them. When he confined a small animal in a large quantity of air, and continued the experiment sufficiently long, he found, that the rate of absorption was greater at the commencement than towards the termination of the experiment; and that, at the former period, there was an excess of oxygen, and at the latter an excess of carbonic acid. This proved to him, that the diminution was dependent upon the absorption of oxygen, not of carbonic acid. His experiments in proof of the exhalation

[1] Traité de Chimie, edit. citat.
[2] Op. citat., p. 437, and Messrs. Allen and Pepys, in Philos. Transactions for 1829.

of carbonic acid, ready formed, by the lungs, are decisive. Spallanzani had asserted, that when certain of the lower animals are confined in gases containing no oxygen, the production of carbonic acid is uninterrupted. Upon the strength of this assertion, M. Edwards confined frogs in pure hydrogen for a length of time. The result indicated, that carbonic acid was produced, and in such quantity, that it could not have been derived from the residuary air in the lungs; as in some cases it was equal to the bulk of the animal. The same results, although to a less degree, were obtained with fishes and snails,—the animals on which Spallanzani's observations were made. The experiments of Edwards were extended to the mammalia. Kittens, two or three days old, were immersed in hydrogen: they remained in this situation for nearly twenty minutes without dying, and on examining the air of the vessel after death, it was found, that they had given off a quantity of carbonic acid greater than could possibly have been contained in their lungs at the commencement of the experiment. The conclusion of Dr. Edwards, from his various experiments, is, "that the carbonic acid expired is an exhalation proceeding wholly or in part from the carbonic acid contained in the mass of blood." Several experiments were subsequently made by M. Collard de Martigny,[1] who substituted nitrogen for hydrogen; and, in all cases, carbonic acid gas was given out in considerable quantity. These and other experiments would seem, then, to show, that in the lungs, carbonic acid is exhaled, and oxygen and nitrogen are absorbed. They would also seem to prove the existence of carbonic acid in venous blood, respecting which so much dissidence has existed amongst chemists, but which ought to be put at rest by the decisive observations of Magnus,[2] which show, that both venous and arterial blood contain oxygen, nitrogen and carbonic acid, which they give up when the blood is placed in vacuo; and farther, that from 10 to 12½ per cent. of oxygen, by volume, exists in arterial blood; whilst in venous blood, there is only one-half that amount; and on the other hand, that there is about 25 per cent., by volume, of carbonic acid in venous blood, to only 20 in arterial.

Allusion has already been made to the fact, that gelatin is not met with in the blood, and to the idea of Dr. Prout,[3] that its formation from albumen must be a *reducing* process. This process he considers to be one great source of the carbonic acid that exists in venous blood. Gelatin contains three or four per cent. less carbon than albumen; it enters into the structure of every part of the animal frame, and especially of the skin; the skin, indeed, contains little else than it. He considers it, therefore, most probable, that a large part of the carbonic acid of venous blood is formed in the skin, and analogous textures. "Indeed," he adds, "we know that the skin of many animals gives off carbonic acid, and absorbs oxygen;—in other words, performs all the offices of the lungs;—a function of the skin perfectly intelligible, on the supposition, that near the surface of the body the albuminous portions of the blood are always converted into gelatin." Gmelin and

[1] Journal de Physiologie, x. 111.
[2] Annal. der Physik und Chemie, lxvi. 177, Philosophical Mag., Dec. 1845, and Annales de Chémie et de Physique, Nov. 1837.
[3] Bridgewater Treatise, Amer. edit., p. 280, Philad., 1834.

Tiedemann, Mitscherlich,[1] and Stromeyer,[2] affirm, on the strength of experiments, that the blood does not contain free carbonic acid, but that it holds a certain quantity in a state of combination, which is set free in the lungs, and commingles with the expired air. The views of Gmelin and Tiedemann, and Mitscherlich on this subject are as follows. It may be laid down as a truth, that the greater part, if not all, of the properties of secreted fluids are not dependent upon any act of the secreting organs, but are derived from the blood, which again, must either owe them to the food, or to changes effected on it within the body. These changes are probably accomplished, in part, during the process of digestion, but are doubtless mainly effected in the lungs by the contact of the blood with the air. Now, most of the animal fluids, when exposed to the air, generate, by the absorption of oxygen, acetic or lactic acid, and this is aided by an elevated temperature, like that of the lungs. In their theory of respiration, the nitrogen of the inspired air is but sparingly absorbed,—by far the greater proportion remaining in the air-cells. The oxygen, on the other hand, penetrates the membranes freely; mingles with the blood; combines partly with the carbon and hydrogen of that fluid, and generates carbonic acid and water, which are thrown off with the expired air; the remainder combines with the organic particles of the blood, forming new compounds, of which the acetic and lactic acids are two; these unite with the carbonated alkaline salts of the blood, and set free the carbonic acid, so that it can be thrown off by the lungs. The acetate of soda—thus formed during the passage of the blood through the lungs—is deprived of its acetic acid by the several secretions, especially by those of the skin and kidneys, and the soda again combines with the carbonic acid, formed during the circulation of the blood through the body, by the decomposition of its organic elements. Carbonate of soda is thus regenerated, and conveyed to the lungs, to be again decomposed by the fresh formation of acids in those organs. Almost the same view is entertained by MM. Dumas and Boussingault, and it is esteemed by Professor Graham[3] to be highly probable.

Another view, in many respects similar, is held by Professor Arnold.[4] As it is more than probable, he remarks, that the carbonic acid occurs in the venous blood, united with some substance from which it is separated with greater or less rapidity by the contact of atmospheric air; and as, further, the carbonate of protoxide of iron greedily withdraws oxygen from the atmosphere, at the same time parting with its carbonic acid and becoming changed into a peroxide, it may be reasonably supposed, that the carbonic acid of venous blood is united with the iron of the red colouring matter, and is set free during the act of respiration, by the reciprocal action of the blood and air. The protoxide, by absorption of oxygen, becomes a peroxide, which, during the circulation of the blood through the capillaries, again parts with its oxygen. Carbon is at the same time eliminated from the blood, and unites with the liberated oxygen to form carbonic acid, which is thrown out by the

[1] Tiedemann und Treviranus, Zeitschrift für Physiol., B. v. H. i.
[2] Schweigger's Journal für Chimie, u. s. w., lxiv. 105.
[3] Elements of Chemistry, Amer. edit., by Dr. Bridges, p. 687, Philad., 1843.
[4] Lehrbuch der Physiologie des Menschen, Zürich, 1836–7.

lungs, whilst oxygen is again absorbed. This is the view embraced by Liebig,[1] who has affirmed, that the amount of iron present in the blood, if in the state of protoxide, is sufficient to furnish the means of transporting twice as much carbonic acid as can possibly be formed by the oxygen absorbed in the lungs.

MM. Chaussier and Adelon,[2] again, regard the whole process of hæmatosis to be essentially *organic* and *vital.* They are of opinion, that an action of selection and elaboration is exerted both as regards the reception of oxygen and the elimination of carbonic acid. But their arguments on this point are unsatisfactory, and are negatived by the facility with which oxygen can be imbibed, and carbonic acid transudes through animal membranes. In their view, the whole process is effected in the lungs, as soon as the air comes in contact with the vessels containing venous blood. Imbibition of oxygen they look upon as a case of ordinary absorption; transudation of carbonic acid as one of exhalation; both of which they conceive to be, in all cases, *vital* actions, and not to be likened to any physical or chemical process.

Admitting that oxygen and a portion of nitrogen absolutely enter the pulmonary vessels, of which we have direct proof, are they, it has been asked, separated from the air in the air-cells, and then absorbed; or does the air enter undecomposed into the vessels, and then furnish the proportion of each of its constituents needed by the wants of the system,—the excess being rejected? Could it be shown, that such a decomposition is actually effected at the point of contact between the pulmonary vessels and the air in the lungs, it would seem, at first, to prove the notion of Mr. Ellis,[3] and of Chaussier and Adelon, that a vital action of selection is exerted; but the knowledge we have attained concerning the transmission of gases through animal membranes would suggest another explanation. The rate of transmission of carbonic acid is greater than that of oxygen; of oxygen greater than that of nitrogen (see p. 69). We can hence understand, that more oxygen than nitrogen may pass through the coats of the pulmonary bloodvessels, and can comprehend the facility with which the carbonic acid, formed in the course of the circulation, may permeate the same vessels, and mix with the air in the lungs. Sir Humphry Davy is of opinion, that the whole of the air is absorbed, and that the surplus quantity of each of the constituents is subsequently discharged. In favour of this view, he remarks that air has the power of acting upon the blood through a stratum of serum, and he thinks that the undecomposed air must be absorbed before it can arrive at the blood in the vessels. It is probable, however, from the different penetrating powers of the gases—oxygen and nitrogen,—that the proportion of those constituents cannot be the same in the interior as at the exterior of the pulmonary vessels. Professor Müller,[4] however, accords with Sir Humphry, and supposes that the air, on entering the lungs, is decomposed in consequence of the affinity of oxygen for the red particles of the blood; carbonic acid

[1] Animal Chemistry, Webster's Amer. edit., p. 261, Cambridge, 1843.

[2] Physiologie de l'Homme, edit. cit., iii. 254.

[3] An Enquiry into the Changes induced on Atmospheric Air, &c., Edinb., 1807; and Further Enquiries, Edinb., 1816.

[4] Handbuch, u. s. w., Baly's translation, p. 334, Lond., 1838.

being formed, which is exhaled in the gaseous form, along with the greater part of the nitrogen.[1]

It has been remarked, that when oxygen is applied to venous blood out of the body, the latter assumes a florid colour. On what part of the blood, then, does the oxygen act? Doubtless, upon the red corpuscles. Facts, hereafter stated in the description of venous blood, have appeared to some to show that these corpuscles are devoid of colour, whilst they exist in chyle and lymph; and that in the lungs, the contact of air changes them to a florid red. The coloration of the blood is, consequently, effected in the lungs; but whether this change be of any importance in hæmatosis is doubtful. In many animals, the red colour does not exist; and, in all, it can perhaps only be esteemed an evidence, that the other important changes have been accomplished in those organs. Of late, the opinion has been revived, that the oxygen of the air acts upon the iron, which Engelhart and Rose[2] had detected in the colouring matter,—but how we are not instructed. It has been asserted, that if the iron be separated, the rest of the colouring matter, which is of a venous red colour, loses the property of becoming scarlet by the contact of oxygen; but this, again, has been denied.

Another view of arterialization has been advanced by Dr. Stevens.[3] According to him, the colouring matter is naturally very dark; is rendered still darker by acids, and acquires a florid hue from the addition of chloride of sodium, and from the neutral salts of the alkalies generally. The colour of arterial blood is ascribed by him to hematin reddened by the salts contained in the serum; the characters of venous blood to the presumed presence of carbonic acid, which, like other acids, darkens hematin; and the conversion of venous into arterial blood to the influence of the saline matter in the serum being restored by the separation of carbonic acid. If we take a firm clot of venous blood, cut off a thin slice, and soak it for an hour or two in repeatedly renewed portions of distilled water; in proportion as the serum is washed away, the colour of the clot deepens; and, when scarcely any serum remains, the colour, by reflected light, is quite black. In this state, it may be exposed to the atmosphere, or a current of air may be blown upon it, without any change of tint whatever; whence it would follow, that when a clot of venous blood, moistened with serum, is made florid by the air, the presence of serum is essential to the phenomenon. The serum is believed, by Dr. Stevens, to contribute to this change by means of its saline matter; for when a dark clot of blood, which oxygen fails to redden, is immersed in a pure solution of salt, it quickly acquires the crimson tint of arterial blood; and loses it again when the salt is abstracted by soaking in distilled water. The facts, detailed by Dr. Stevens, were confirmed

[1] See, on this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., Pt. xxxii. p. 365, Lond., Aug., 1848.
[2] Edinb. Med. and Surg. Journal for Jan., 1827.
[3] Observations on the Healthy and Diseased Properties of the Blood, Lond., 1832; and Proceedings of the Royal Society for 1834–5, p. 334.

by Mr. Prater,[1] and by Dr. Turner,[2] of the London University. The latter gentleman, assisted by Professor Quain, of the same institution, performed the following satisfactory experiment. He collected some perfectly florid blood from the femoral artery of a dog; and on the following day, when a firm coagulum had formed, several thin slices were cut from the clot with a sharp penknife, and the serum was removed from them by distilled water, which had just before been briskly boiled, and allowed to cool in a well-corked bottle. The water was gently poured on these slices, so that while the serum was dissolving, as little as possible of the colouring matter should be lost. After the water had been poured off, and renewed four or five times, occupying in all about an hour, the moist slices were placed in a saucer at the side of the original clot, and both portions were shown to several medical friends, all of whom unhesitatingly pronounced the unwashed clot to have the perfect appearance of arterial blood, and the washed slices to be as perfectly venous. On restoring one of the slices to the serum it shortly recovered its florid colour; and another slice, placed in a solution of bicarbonate of soda, instantly acquired a similar hue;—yet, as we have seen, carbonate of soda is considered by Messrs. Gmelin, Tiedemann, and Mitscherlich, to exist in venous or black blood!

In brightening, in this way, a dark clot by a solution of salt or a bicarbonate, Dr. Turner found the colour to be often still more florid than that of arterial blood; but the colours were exactly alike when the salt was duly diluted. Dr. Turner remarks, that he is at a loss to draw any other inference from this experiment, than that the florid colour of arterial blood is not due to oxygen; but, as Dr. Stevens suggests, to the saline matter of the serum. The arterial blood, which was used, had been duly oxygenized within the body of the animal, and should not in that state have lost its tint by the mere removal of its serum; and he adds,—the change from venous to arterial blood appears, contrary to the received doctrine, to consist of two parts essentially distinct; one a chemical change, essential to life, accompanied by absorption of oxygen, and evolution of carbonic acid; the other dependent on the saline matter of the blood, which gives a florid tint to the colouring matter after it has been modified by the action of oxygen. "Such," says Dr. Turner, "appears to be a fair inference from the facts above stated; but being drawn from very limited observation, it is offered with diffidence, and requires to be confirmed or modified by future researches." But we are perhaps scarcely justified in inferring, from the experiments of Stevens, Turner, and others, more than the fact, that a florid hue is communicated to blood by sea-salt, and by the neutral salts of the alkalies in general, and indeed by admixture with sugars; whilst acids render it still darker. The precise changes that occur during the arterialization of the blood in the lungs are still unknown.

Since Dr. Stevens first published his views, the subject has been farther investigated by Dr. William Gregory, and Mr. Irvine. They

[1] Experim. Inquiries in Chemical Physiology, Part i., on the Blood, Lond., 1832.
[2] Elements of Chemistry, 5th edit., by Dr. Bache, p. 609, Philad., 1835.

introduced portions of clot, freed by washing from serum, into vessels containing pure hydrogen, nitrogen, and carbonic acid, placed over mercury. As soon as the strong saline solution came in contact with them, the colour of the clot, in all the gases, changed from black to bright red; and the same change was found to take place in the Torricellian vacuum. On repeating these experiments with the serum of blood, and a solution of salt in water of equal strength with the serum, no change took place until atmospheric air, or oxygen gas, was admitted. Whence it appears—as properly inferred by the late Mr. Egerton A. Jennings, who published an interesting "Report on the Chemistry of the Blood as Illustrative of Pathology,"[1]—that though saline matter may be necessary to effect the change of colour of venous to that of arterial blood, with so dilute a saline solution as that which exists in serum, the presence of oxygen is likewise necessary. Dr. Davy[2] dissents, however, from these conclusions, and is disposed to infer, from all the facts with which he is acquainted, that the colour of the blood, whether venous or arterial,—that is, dark or florid,—is independent of the saline matter in the serum, considered in relation to agency; and that, according to the commonly received view, oxygen is the cause of the bright hue of the arterial fluid, and its consumption and conversion into carbonic acid the cause of the dark hue of the venous,—the saline matter being negative in regard to colour; and its chief use, in his opinion, being "to preserve the red globules from injury, prevent the solution of their colouring matter, retain their forms unchanged, and to bear them in their course through the circulation.

In the difficulty of the subject, an idea has been entertained, that the change from arterial to venous blood, and conversely, as regards colour, is dependent in a great measure on a difference in the shape of the blood corpuscles; and is therefore owing rather to physical than to chemical changes in them. Such is the opinion of Kaltenbrunner, Schultz, Reuter, Gulliver, Harless, Kirkes and Paget,[3] Nasse, Mulder, Funke, and others. It is of course opposed to that of Liebig, already stated. Mulder[4] explains the difference between the colour of arterial and venous blood as follows. Two oxides of protein are formed in the act of respiration, which have a strong plastic tendency, and solidify around each corpuscle, making the capsule thicker, and better qualified to reflect light. Each corpuscle of arterialized blood is then, in reality, invested with a complete envelope of buffy coat, which gradually contracts, and speedily forms cupped or bi-concave surfaces, which are favourable to the reflection of light. On reaching the capillaries, the coating of the oxides of protein is removed, and the corpuscles, losing their opaque investment, and cupped form, no longer

[1] Transactions of the Provincial Medical and Surgical Association, vol. iii., Worcester and London, 1835.

[2] Researches, Physiological and Anatomical, Dunglison's Amer. Med. Lib. edit., p. 96, Philad., 1840.

[3] Manual of Physiology, 2d Amer. edit., p. 59, Philad., 1853.

[4] Versuch einer Allgemeinen Physiologischen Chemie, cited by Dr. Day in Simon, Animal Chemistry, Sydenham edit., p. 193, Lond., 1845; and Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 342, Lond. and Edinb., 1849.

reflect light, and the blood assumes the venous tint. Dr. G. O. Rees,[1] however, considers this explanation to be entirely hypothetical and erroneous. He rejects the idea of a layer of plastic oxy-protein being deposited on the blood corpuscles during respiration; and instead of considering the hematin as undergoing no change, and maintaining the same condition in arterial and venous blood, he looks upon it as the cause of the change of colour in the blood by virtue of some chemical alteration, which takes place in it, but whose nature—if there be any such alteration—remains a mystery. He has himself advanced the following ingenious theory.[2] He found by analysis, that the corpuscles of venous blood contain fatty matter in combination with phosphorus. This does not exist in arterial blood, or, at most, is met with in it in very small quantity. During respiration the oxygen of the inspired air unites with the phosphorus and fatty matter, and combustion takes place; of which the products are water and carbonic acid from the union of the oxygen with the elements of the fatty matter; and phosphoric acid from the union of the oxygen with the phosphorus. The carbonic acid and water are exhaled, and appear in the expired air; the phosphoric acid attracts the soda of the liquor sanguinis from its combination with albumen and lactic acid, and forms a tribasic phosphate of soda,—a salt, which possesses in a marked degree the property of communicating a bright colour to hematin.

It is proper to add, that Burdach, Müller, Bruch, Marchand, Scherer, and others, have failed to detect by the microscope any difference in the external form of the corpuscles in arterial and in venous blood. Still, Dr. John Reid[3] is disposed to conclude, that the change in the blood from the venous to the arterial hue in the lungs is a physical and not a chemical action; and "that though there is pretty strong evidence in favour of the opinion, that this physical change consists in an alteration of the form of the red corpuscles, yet it is not free from doubt." The author has, indeed, always had great doubts on the matter; and must continue to have them, until such a change as is supposed to be produced in the shape of the corpuscles is demonstrated. It remains to be proved, that the blood—as Dr. Carpenter[4] now maintains—"is *darkened* by whatever tends to *distend* the corpuscles, so as to render them flat, or biconvex, whilst it is brightened by whatever tends to *empty* them, so as to render them more deeply biconcave than usual. And observation of the effects of oxygen and carbonic acid, respectively, upon the form of the corpuscles, confirms the idea, that this is the mode in which these agents affect their colour, for the former causes their contraction, and renders their cell walls thick and granular so as to increase their power of reflecting light; whilst the latter, producing a dilatation of the corpuscles, thins their cell walls, and enables them to transmit light more readily." Recently,

[1] Lond. Med. Gazette, 1844–5, p. 840. See, also, Mulder, op. cit., p. 341.
[2] Proceedings of the Royal Society, June 3, 1847, and Lond., Edinb., and Dublin Philos. Magazine for July, 1848.
[3] Art. Respiration, Cyclop. of Anat. and Physiology, Pt. xxxii. p. 361, London, August, 1848.
[4] Principles of Human Physiology, Amer. edit., p. 195, Philad. 1855.

Moleschott[1] and Bruch have instituted a fresh set of observations to show, that the colour of the blood is independent of the shape of the corpuscles. The former affirms, that neither oxygen nor carbonic acid, which are concerned in the coloration of that fluid, change perceptibly the shape or size of the blood-corpuscles in man, the mammalia, fowls, or frogs; and he affirms, that very dilute solutions of chloride of sodium or of sulphate of soda, which produce no change in the shape of the corpuscles sensibly redden the blood. Messrs. Todd and Bowman[2] carefully examined two portions of the same blood after they had been agitated in oxygen and carbonic acid gas, and thus been rendered respectively scarlet and purple, and failed to detect any well-marked difference in shape between the corpuscles of the two specimens. Bruch[3] has also given additional reasons for the belief, that the colour of the blood is independent of the shape of the corpuscles. He is of opinion, that the natural colour is probably that of venous blood; and that the vermilion hue is communicated to arterial blood by the combination of the hematin with oxygen.[4]

The author has always been of opinion, that the question will have to be settled by the chemist rather than by the physicist; and that the change of colour is owing to the different effects of agents—of which oxygen is the chief—on the hematin; but as to the precise mode in which the phenomena are accomplished we are in want of information.

The slight diminution, if it exist, in the specific gravity of arterial blood has been considered, but we know not on what grounds, to depend on the transpiration, which takes place into the air-cells, and was formerly thought to be owing to the combustion of oxygen and hydrogen. This will engage us in another place;—as well as the changes produced in its capacity for heat, on which several ingenious speculations have been founded to account for ANIMAL TEMPERATURE. The other changes are at present inexplicable; and can only be understood by minute chemical analysis, and by an accurate comparison of the two kinds of blood,—venous and arterial. This has been carefully done by Simon, who infers, from his analyses, that arterial blood generally contains less solid residue than venous blood; and less fat, albumen, hematin, extractive matter, and salts; but further experiments are demanded.

The blood corpuscles of arterial blood contain less colouring matter than those of venous blood.[5]

It is manifest, from the preceding detail, that our knowledge regarding the precise changes effected on the air and the blood by respiration is by no means definite. We may, however, consider the following points established. In the first place:—the air loses a part of its oxygen and nitrogen; but this loss varies according to numerous circum-

[1] Zur Lehre von der Blutfarbe, in Münchn. Illustr. Med. Zeit., Mars, 1853; and Canstatt's Jahresb., 1853, i. 161, Würzburg, 1854.

[2] Physiological Anatomy and Physiology of Man, Pt. iv., p. 298, Lond., 1852; or Amer. edit., Philad., 1853.

[3] Ueber die Blutfarbe, in Siebold und Kölliker's Zeitschr.; and Canstatt, loc. cit.

[4] J. Béclard, Traité Élémentaire de Physiologie, p. 295, Paris, 1855.

[5] For various analyses of the two kinds of blood, see Simon, op. cit., p. 194.

stances. 2dly. It is found to have acquired carbonic acid, the quantity of which is also variable. 3dly. The bulk of the air is diminished; but the extent of this likewise differs. 4thly. The blood, when it attains the left side of the heart, has a more florid colour. 5thly. This change appears to be caused by the contact of oxygen. 6thly. The blood in the lungs gets rid of a quantity of carbonic acid. 7thly. The oxygen taken in is more than necessary for the carbonic acid formed. 8thly. The constituents of the air pass directly through the coats of the pulmonary vessels, and certain portions of each are discharged or retained, according to circumstances. 9thly. A quantity of aqueous vapour is discharged from the lungs; the expired air is indeed saturated with it. 10thly. The expired air has always a temperature at or near 99°; and, lastly, it would appear, from the facts stated elsewhere, that the red corpuscles are not the only constituent of the blood that undergoes a change in the respiratory process; and that the fibrin of venous blood most nearly resembles albumen, whilst that of arterial blood contains more oxygen.

c. *Cutaneous Respiration, &c.*

A question has arisen, whether absorption and exhalation of air, and conversion of blood from venous to arterial, take place in any other part of the body than the lungs. The reasons, urged in favour of the affirmative of this question, are;—that, in the lower classes of animals, the skin is manifestly the organ for the reception of air; that the mucous membrane of the lungs evidently absorbs air, and is simply a prolongation of the skin, resembling it in texture; and, lastly, that when a limited quantity of air has been placed in contact with the skin of a living animal, it has been absorbed, and found to have experienced the same changes as are effected in the lungs. Mr. Cruikshank[1] and Mr. Abernethy[2] analyzed air in which the hand or foot had been confined for a time; and detected in it a considerable quantity of carbonic acid. Jurine, having placed his arm in a cylinder hermetically closed, found, after it had remained there two hours, that oxygen had disappeared, and 0.08 of carbonic acid had been formed. These results were confirmed by Gattoni;[3] and from experiments by Professor Scharling, referred to before, the amount of carbon exhaled by the skin in the twenty-four hours, has been estimated at two ounces; but this is probably beyond the real amount. On the other hand, Drs. Priestley,[4] Klapp,[5] and Gordon[6] could never perceive the least change in the air under such circumstances. Perhaps in these, as in all cases where the respectability of testimony is equal, the positive ought to be adopted rather than the negative. It is probable, however, that absorption is effected with difficulty; and that the cuticle, as we have elsewhere shown, is placed on the outer surface to obviate the bad

[1] Experiments on the Insensible Perspiration, &c., Lond., 1795.
[2] Surgical and Physiological Essays, Part ii. p. 115, Lond., 1793.
[3] Dict. des Sciences Médicales, art. Peau.
[4] Experiments and Observations on Different Kinds of Air, ii. 193, and v. 100, Lond., 1774.
[5] Inaugural Essay on Cuticular Absorption, p. 24, Philad., 1805.
[6] Ellis's Inquiry into the Changes of Atmospheric Air, &c., p. 355, Edinb., 1837.

effects that would be induced by heterogeneous gaseous, miasmatic, or other absorption. We have seen that some of the deleterious gases, as sulphuretted hydrogen, are most powerfully penetrant, and, if they could enter the surface of the body with readiness, unfortunate results might supervene. In those parts where the cuticle is extremely delicate, as in the lips, some conversion of venous into arterial blood may be effected, and this may be a great cause of their florid colour.

According to this view, the arterialization of the blood occurs in the lungs chiefly, owing to their formation being so admirably adapted to the purpose; and it is not effected in other parts, because their arrangement is unfavourable for such a result.

d. *Effects of the Section of certain Nerves on Respiration.*

It remains to inquire into the effect produced on the lungs by the cerebro-spinal and spinal nerves distributed to them,—or rather, into what is the effect of depriving the respiratory organs of their nervous influence from the brain and spinal marrow. The only encephalic nerves, distributed to them, are the pneumogastric or eighth pair of Willis, which, we have seen, are sent, as their name imports, to both the lungs and stomach. The section of these nerves early suggested itself to physiologists, but it is only in recent times that the phenomena resulting from it have been clearly comprehended. The operation appears to have been performed as long ago as the time of Rufus of Ephesus, and was afterwards repeated by Chirac, Bohn, Duverney, Vieussens, Schräder, Valsalva, Morgagni, Haller, and numerous other distinguished physiologists. It is chiefly, however, in recent times, and especially from the labours of Dupuytren, Dumas, De Blainville, Provençal, Legallois, Magendie, Breschet, Hastings, Broughton, Sir Benjamin Brodie, Wilson Philip, Longet, John Reid, and others, that the precise effects upon the respiratory and digestive functions have been appreciated.

When these nerves are divided in a living animal, on both sides at once, the animal dies more or less promptly; at times immediately after their division, but it sometimes lives for a few days;—M. Magendie says never beyond three or four. The effects produced upon the voice, by their division above the origin of the recurrents, will be referred to under another head. Such division, however, does not simply implicate the larynx; it necessarily affects the lungs, as well as the stomach. As regards the larynx, the same results, according to M. Magendie,[1] are produced by dividing the trunk of the pneumogastric above the origin of the recurrents as by the division of the recurrents themselves; the muscles, whose function it is to dilate the glottis, are paralyzed; and consequently, during inspiration, no dilatation takes place; whilst the constrictors, which receive their nerves from the superior laryngeal, preserve all their action, and close the glottis, at times so completely, that the animal dies at once from suffocation. But if the division of those nerves should not induce instant death in this manner, phenomena follow, considerably alike in all cases, which go on until the death of the animal. These are the fol-

[1] Précis, &c., 2de édit., ii. 355.

lowing:—respiration is, at first, difficult; the inspiratory movements are more extensive and rapid, and the animal's attention appears to be particularly directed to them; the locomotive movements are less frequent, and evidently fatigue; frequently, the animal remains entirely at rest; the formation of arterial blood is not prevented at first, but soon, on the second day for instance, the difficulty of breathing augments, and the inspiratory efforts become gradually greater. The arterial blood has now no longer the vermilion hue proper to it. It is darker than it ought to be: its temperature falls; respiration requires the exertion of all the respiratory powers; the body gradually becomes cold, and the animal dies. On opening the chest, the air-cells, bronchi, and frequently the trachea, are found filled by a frothy fluid, which is sometimes bloody; the substance of the lung is tumid; the divisions and even the trunk of the pulmonary artery are greatly distended with dark, almost black, blood; and extensive effusions of serum and even of blood are found in the parenchyma of the lungs. Experiments have, likewise, shown that, in proportion as these phenomena appeared, the animal consumed less and less oxygen, and gave off a progressively diminishing amount of carbonic acid.

From the phenomena that occur after the section of the nerves on both sides, it would seem to follow, that the first effect is exerted upon the tissues of the lungs, which, being deprived of nervous influence, are no longer capable of exerting their ordinary tonicity and muscularity. Respiration, consequently, becomes difficult; the blood no longer circulates freely through the capillary vessels of the lungs; the consequence is, that transudation of its serous portions, and occasionally effusion of blood, owing to rupture of small vessels, takes place, filling the air-cells more or less; until, ultimately, all communication is prevented between the inspired air and the bloodvessels, and the conversion of venous into arterial blood is completely precluded. Death is then the inevitable and immediate consequence. The division of the nerve on one side affects merely the lung of the corresponding side. Life can be continued by the action of one lung only: it is, indeed, a matter of astonishment how long some individuals have lived when the lungs have been almost wholly obstructed. Every morbid anatomist has had repeated opportunities of observing, that for a length of time prior to dissolution, in cases of pulmonary consumption, the process of respiration must have been carried on by a very small portion of lung.

From his experiments on this subject, Sir Astley Cooper infers, that the pneumogastric nerve is most important;—1st, in assisting in the maintenance of the function of the lungs, by contributing to the change of venous into arterial blood; 2dly, in being necessary to the act of swallowing; and 3dly, in being essential to the digestive process. Dr. John Reid is of opinion, that the pulmonary branches seem to be nerves concerned chiefly in transmitting to the medulla oblongata the impressions that excite respiratory movements, and are thus principally afferent nerves; but it is possible, he thinks, that they contain motor filaments also.[1]

[1] Edinb. Med. and Surg. Journ., April, 1839; and art. Par Vagum in Cyclop. of Anat. and Physiol., Part xxvii. p. 896, March, 1846.

The experiments of Dr. Wilson Philip[1] and others show, moreover,—what has been more than once inculcated,—the great similarity between the nervous and galvanic fluids. The state of dyspnœa induced by the division of the pneumogastric nerves was, in numerous cases, entirely removed by the galvanic current passed from one divided extremity to the other. The results of these experiments induced him to try galvanism in cases of asthma. By transmitting its influence from the nape of the neck to the pit of the stomach, he gave decided relief in every one of twenty-two cases; four of which occurred in private practice, and eighteen in the Worcester Infirmary.

Sir A. Cooper[2] instituted similar experiments on the phrenic nerves. As soon as they were tied, the most determined asthma was produced; breathing went on by means of the intercostal muscles; the chest was elevated to the utmost by them; and in expiration the chest was as remarkably drawn in. The animals did not live an hour; but they did not die suddenly, as they do from pressure on the carotid and vertebral arteries. The lungs appeared healthy, but the chest contained more than its natural exhalation. He also tied the great sympathetic; which produced little effect; the heart appeared to beat more quickly and feebly than usual. The animal was kept seven days, when one nerve was found ulcerated through; the other nearly so at the situation of the ligatures. On examination, no particular alteration of any organ was observed. Lastly, Sir Astley tied all three nerves on each side, the pneumogastric, phrenic, and great sympathetic: the animal lived little more than a quarter of an hour, and died of dyspnœa. From these experiments, he infers, that the sudden death, which he found to follow pressure on the sides of the neck, cannot be attributed to any injury of the nerves, but to an impediment to the due supply of blood to the great centres of nervous influence.

The nervous centre of the respiratory movements is the vesicular neurine in the upper part of the medulla oblongata. Into it the pneumogastric nerves, which appear to be the chief excitors of respiration, may be traced; and from it the different motor or efferent nerves proceed either directly or indirectly. Of these, the most important is the phrenic. The vesicular neurine of the medulla receives the impression of the *besoin de respirer* or necessity of breathing; and thence it is reflected along the appropriate nerves to the muscles concerned in inspiration.[3]

e. *Respiration of Animals.*

In concluding the subject of respiration, we may briefly advert to the different modes in which the process is effected in the classes of animals, and especially in birds,—the respiratory organs of which constitute one of the most singular structures of the animal economy. The lungs themselves are comparatively small, and adherent to the chest,—where they seem to be placed in the intervals of the ribs.

[1] Experimental Inquiry into the Laws of the Vital Functions, &c., 2d edit., p. 223, Lond., 1818; also, Journal of Science and Arts, viii. 72.

[2] Op. cit., p. 475.

[3] See, on all this subject, Longet, Traité de Physiologie, ii. 328, Paris, 1850.

They are covered by the pleura on their under surface only, so that they are, in fact, on the outside of the cavity of the chest. A great part of the thorax, as well as of the abdomen, is occupied by membranous air-cells, into which the lungs open by considerable apertures. Besides these cells, a considerable portion of the skeleton in many birds forms receptacles for air, and if we break a long bone of a bird of flight, and blow into it when the body of the animal is immersed in water, bubbles of air will escape from the bill. The object, of course, of all this arrangement is to render the body light, and thus to facilitate its motions. Hence, the largest and most numerous bony cells are found in such birds as have the highest and most rapid flight, as the eagle. The barrels of the quills are likewise hollow, and can be filled with air, or emptied at pleasure. In addition to the uses just mentioned, these air receptacles diminish the necessity for breathing so frequently in the rapid and long-continued motions of certain birds, and in the great vocal exertions of those that sing.

In fishes, in the place of lungs we find *branchiæ* or *gills*, which are placed behind the head on each side, and have a movable *gill-cover*. By the throat, which is connected with the gills, the water is conveyed to, and distributed through them: in this way, the air, contained in the water, which, according to Biot, Von Humboldt[1] and Provençal, Configliachi, and Thomson,[2] is richer in oxygen than that of the atmosphere, having from 29 to 32 parts in the 100, instead of 20 or 21, comes in contact with the blood circulating through the gills. The water is afterwards discharged through the branchial openings,—*aperturæ branchiales*,—and, consequently, they do not expire along the same channel as they inspire.

Lastly, in the insect tribe,—in the white-blooded animal,—we find the function of respiration effected altogether by the surface of the body; at least, so far as regards the reception of air, which enters through apertures termed *stigmata*, the external terminations of *tracheæ* or air tubes, whose office it is to convey air to different parts of the system.

In all these cases, we find precisely the same changes effected upon the inspired air;—and especially, that oxygen has disappeared; and that carbonic acid of a bulk nearly equal to that of the organ is met with in the residuary air.[3]

CHAPTER IV.

CIRCULATION.

The next function to be considered is that by which the products of the various absorptions, converted into arterial blood in the lungs, are

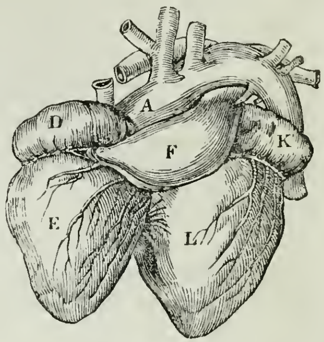
[1] Mémoires de la Société d'Arcueil i. 252, and ii. 400.

[2] Dr. Thomson found that 100 cubic inches of the water of the river Clyde contained 3·113 inches of air; and that the air contained 29 per cent. of oxygen. Edinb. New Philosoph. Journal, xxi. 370, Edinb., 1836.

[3] See Carpenter's Principles of Comparative Physiology, Amer. edit., Philad. 1854.

distributed to every part of the body,—a function most important to the physiologist and the pathologist, and without a knowledge of which it is impossible for the latter to comprehend the doctrine of disease.

Fig. 91.



Heart of the Dugong.

D. Right auricle. E. Right ventricle. K. Left auricle. L. Left ventricle. F. Pulmonary artery. A. Aorta.

Assuming the heart to be the great organ of the function, the circulatory fluid must set out from it, be distributed through the lungs, undergo aeration there, be sent to the opposite side of the heart, whence it is distributed to every part of the system by efferent vessels, and be returned by veins or afferent vessels to the right side, from which it set out,—thus performing a complete circuit.

The lower classes of animals differ essentially, as we shall find hereafter, in their organs of circulation: whilst in some, the apparatus appears to be confounded with the digestive; in others, the blood is propelled without any great central organ; and in others, again, the heart is but a single organ. In man, and in the upper classes of animals, the heart is *double;*—consisting of two sides, or really two hearts, separated from each other by a septum. In the dugong, the two ventricles are almost entirely detached from each other.

As all the blood of the body has to be emptied into this central organ, and to be subsequently sent from it; and as its flow is continuous, two cavities are required in each heart,—the one to receive the blood, the other to propel it. The latter distinctly contracts and dilates alternately. The cavity or chamber of each heart, that receives the blood, is called *auricle*, and the vessels that transport it thither are *veins;* the cavity by which the blood is projected forwards is called *ventricle*, and the vessels, along which the blood is sent, are *arteries*. One of these hearts is entirely appropriated to the circulation of venous blood, and hence has been called *venous heart*,—also *right* or *anterior* heart, from its situation,—and *pulmonary*, from the pulmonary artery arising from it. The other is for the circulation of arterial blood, and is hence called *arterial heart*, also *left* or *posterior*, from its situation,—*aortic heart*, because the aorta arises from it; and *systemic*, because the blood is sent from it to the general system.

Fig. 92.

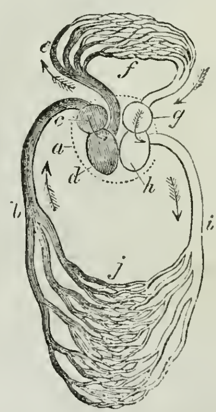


Diagram of the Circulating Apparatus in Mammals and Birds.

a. The heart, containing four cavities. *b*. Vena cava, delivering venous blood into *c*, the right auricle. *d*. The right ventricle, propelling venous blood through *e*, the pulmonary artery, to *f*, the capillaries of the lungs. *g*. The left auricle, receiving the aerated blood from the pulmonary vein, and delivering it to the left ventricle, *h*, which propels it through the aorta, *i*, to the systemic capillaries, *j*, whence it is collected by the veins, and carried back to the heart through the vena cava, *b*.

The whole of the vessels communicating with the right heart contain venous blood; those of the left side arterial blood.

If we consider the heart to be the centre, two circulations must be accomplished, before the blood, setting out from one side of the heart, performs the whole circuit. One of these consists in the transmission of the blood from the right side of the heart, through the lungs, to the left; the other, in its transmission from the left side, along the arteries, and by means of the veins, back to the right. The former is called the *lesser* or *pulmonic*, the latter the *greater* or *systemic* circulation. The organs, by which these are effected, will require a more detailed examination.

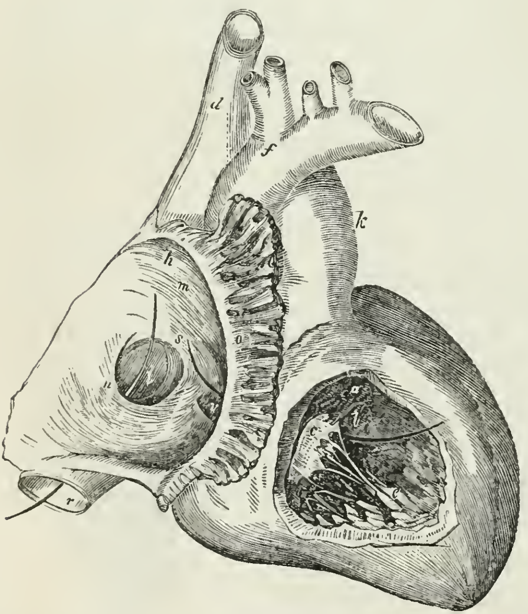
1. ANATOMY OF THE CIRCULATORY ORGANS.

The circulatory apparatus is composed of organs by which the blood is put in motion, and along which it passes during its circuit.

a. *Heart.*

To simplify the consideration of the subject we shall consider the heart double; and that each system of circulation is composed of a *heart;* of *arteries*, through which the blood is sent from the heart; and of *veins*, by which the blood is returned to it. At the minute termination of each of these is a *capillary system.* We shall first describe the central organ as forming two distinct hearts; and afterwards the two united.

Fig. 93.



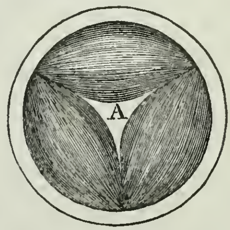
Heart placed with its Anterior Surface upwards, and its Apex turned to the right hand of the spectator. The Right Auricle and Right Ventricle are both opened.

Parts in right auricle:—*h*. Entrance of vena cava superior, which is itself marked *d*. Inferior cava, marked *r*, has a probe passed through it into the auricle. *m*. The smooth part of the auricle. *o*. Musculi pectinati, seen in the auricular appendix which is cut open. *n*. Eustachian valve placed over the mouth of the inferior cava. *i*. Fossa ovalis, or vestige of the foramen ovale. *s*. Annulus ovalis. The probe leading from *s* into the right ventricle passes through the auriculo-ventricular opening. *v*. Mouth of the coronary vein. Parts in the right ventricle, in which the other end of the probe, from *s*, appears:—*a*. Cavity of conus arteriosus, leading to the pulmonary artery, *k*. *l*. Convex septum between the ventricles. *c*. Anterior segment of the tricuspid valve, connected by slender cords, the chordæ tendineæ, to the musculi papillares, *e*. *f*. The aorta.

The *pulmonic*, *right*, or *anterior heart*, called also *heart of black blood*, is composed of an auricle and a ventricle. The *auricle*, so termed from some resemblance to a small ear, is situate at the base of the organ, and receives the whole of the blood returned from various parts of the body by three veins;—the two venæ cavæ, and the coronary. The *vena cava descendens* terminates in the auricle in the direction of the aperture by which the auricle communicates with the ventricle. The *vena cava ascendens*, the termination of which is directed more backwards, has the remains of a valve which is much larger in the fœtus, called *valve of Eustachius.* The third vein is the *cardiac* or *coronary;* it returns the blood from the heart which has been carried thither by the coronary artery. In the septum between the right and left auricle, there is a superficial depression, about the size of the point of the finger, which is the *vestige* of the foramen ovale,—an important part of the circulatory apparatus of the fœtus. The opening through which the auricle projects its blood into the ventricle, is situate downwards and forwards, as seen in Fig. 93. The inner surface of the *proper auricle*, or that which more particularly resembles the ear of a quadruped,—the remainder being sometimes called *sinus venosus* or *sinus venarum cavarum*,—is distinguished by having a number of *fleshy pillars* in it, which, from their supposed resemblance to the teeth of a comb, are called *musculi pectinati.* They are mere varieties, however, of the *columnæ carneæ* of the ventricles.

The right *ventricle* or *pulmonary ventricle* is situate in the anterior part of the heart; the base and apex corresponding to those of the heart. Its cavity is generally greater than that of the left side, and its parietes not so thick, owing to its having merely to force the blood through the lungs. It communicates with the auricle by the *auriculo-ventricular opening—ostium venosum;* and the only other opening into it is that which communicates with the interior of the pulmonary artery. The opening between the auricle and ventricle is furnished with a tripartite valve, called *tricuspid* or *triglochin;* and the pulmonary artery has three others, the *sigmoid* or *semilunar.* From the edge of the tricuspid valve, next the apex of the heart, small, round, *tendinous cords*, called *chordæ tendineæ*, are sent off, which are fixed, as represented in Fig. 93, to the extremities of a few strong *columnæ carneæ*—called *musculi papillares.* These tendinous cords are of such a length as to allow the valve to be laid against the sides of the ventricle, in the dilated state of that organ; and to admit of its being pushed back by the blood, until a nearly complete septum is formed during the contraction of the ventricle. The *semilunar* or *sigmoid valves* are three in number, situate around the artery. When these fall together, there must necessarily be a space left between them. To obviate the inconvenience that would result from the existence of such a free space, a small granular body is attached to the middle of

Fig. 94.



Semilunar Valves closed.

Fig. 95.

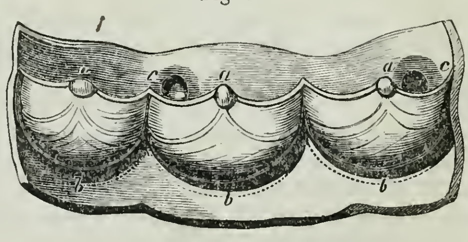
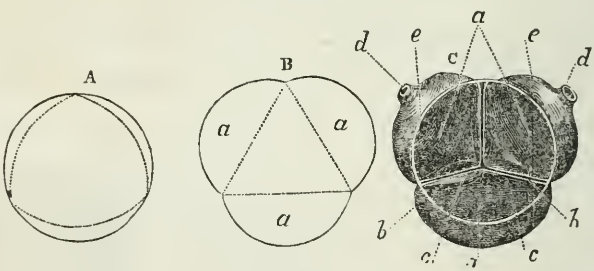


Diagram of the Semilunar Valves of the Aorta.

a. Corpus Arantii on the free border. *b.* Attached border. *c.* Orifices of the coronary arteries.

the margin of each valve; and these, coming together, as at A, Fig. 94, when the valves are shut down, complete the diaphragm, and prevent any blood from passing back to the heart. These small bodies are termed, from their reputed discoverer, *corpuscula Arantii*, and also *corpuscula Morgagnii;* or, from their resemblance to the seed of the sesamum, *corpuscula sesamoidea*. The valves, when shut, are concave towards the lungs, and convex towards the ventricle. Immediately above them the artery bulges out, forming three sacculi or sinuses, called *sinuses of Valsalva*. These are often said to be partly formed by the pressure of the blood upon the sides of the vessel. The structure is doubtless ordained, and is admirably adapted for a specific purpose,—namely, to allow the free edges of the valves to be readily caught by the refluent blood, and thus facilitate their closure. Within the right ventricle, and especially

Fig. 96.



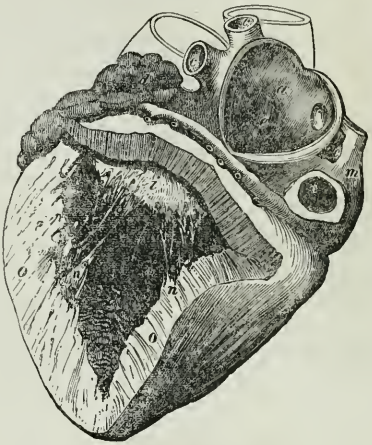
Sections of Aorta, to show the action of the Semilunar Valves.

A. The valves, represented by the dotted lines, in contact with the arterial walls, represented by the continuous outer line. B. The arterial wall distended into three pouches (*a*), and drawn away from the valves, which are straightened into the form of an equilateral triangle, as represented by the dotted lines. C. The margins of the valves when in action:—*a*. The pouches between the valves and the arterial wall. *b*. The apposed edges. *c*. The apposed surfaces of the valves. *d*. Mouths of coronary arteries. *e*. Cut edge of aorta.

towards the apex of the heart, many strong eminences are seen, *columnæ carneæ* (Fig. 93). These run in different directions, but the strongest of them longitudinally with respect to the ventricle. They are of various sizes, and form a beautifully reticulated texture. Their chief use probably is, to strengthen the ventricle, and prevent it from being over-distended; in addition to which they may tend to mix the different products of absorption.

The *corporeal*, *left*, *aortic*, or *systemic* heart,—called also *heart of red blood*,—has likewise an auricle and a ventricle. The *left auricle* is considerably thicker and stronger but smaller than the right; and it is likewise divided into *sinus* (*sinus arteriosus*) and *proper auricle*, which form a common cavity. The columns in the latter are like those of the right, but less distinct. From the under part of the auricle, a circular passage, termed *ostium arteriosum* or "auricular orifice," leads to the posterior part of the base of the cavity of the left ventricle. The left auricle receives the blood from the pulmonary veins. The *left* or *aortic ventricle* is situate at the posterior and left part of the heart. Its sides are three times thicker and stronger than those of the right ventricle, to adapt it for the much greater force it has to exert; for, whilst the right ventricle merely sends its blood to the lungs, the left ventricle transmits it to every part of the body. Its muscular force has been estimated at twice that of the right.[1] It is narrower and rounder, but considerably longer, than the right ventricle, and forms the apex of the heart. The internal surface of this ventricle has the same general appearance as the other; but differs from it in having larger, more numerous, firmer, and stronger columnæ carneæ. In the aperture of communication with the corresponding auricle, there is here, as in the opposite side of the heart, a ring or zone, from which a valve, essentially like the tricuspid, goes off. It is stronger, however, and divided into two principal portions only; the chordæ tendineæ and *musculi papillares*, are also stronger and more numerous. This valve has been termed *mitral*, from some supposed resemblance to a bishop's mitre, and *bicuspid*. At the fore and right side of the valve, and behind the commencement of the pulmonary artery, a round opening exists, which is the mouth of the aorta. Here are three *semilunar valves*, with their *corpuscula Arantii;* like those of the pulmonary artery, but a little stronger; and, on the outer side of the semilunar valves, are the *sinuses of Valsalva*, a little more prominent than those of the pulmonary artery.

Fig. 97.



Heart seen from behind, and having the Left Auricle and Ventricle opened.

Parts in left auricle:—*a*. Smooth wall of auricular septum. *c*, *c*, *c*. Openings of the four pulmonary veins. *d*. Left auricular appendage. *e*. Slight depression in the septum, corresponding to the fossa ovalis on the right side. A probe is seen, which passes down into the ventricle through the auriculo-ventricular orifice. Parts in left ventricle:—*i*. Posterior segment of the mitral valve, behind which is the probe passed from the left auricle. *n*, *n*. The two groups of musculi papillares. *o*. Section of the thick walls of this ventricle, which may be compared with that of the walls of the right ventricle, Fig. 93. *r*. Entrance of inferior cava.

The structure of the two hearts is the same. A serous membrane covers both. It is an extension of the inner membrane of the pericardium.

The substance of the heart is essentially muscular. The fibres run in different directions, longitudinally and transversely, but most of them obliquely. Many pass over the point, from one heart to the other, and all are so involved as to render it difficult to unravel them. The cavities are lined by a thin membrane, *endocardium*, which differs somewhat in the two hearts;—being in one a prolongation of the inner coat of the aorta, and in the other of the venæ cavæ. On this account, the inner coat of the left heart is but slightly extensible, more easily ruptured, and considerably disposed to ossify; that of the right heart, on the other hand, is very extensible, not readily ruptured, and but little liable to ossify. The endocardium invests all the elevations and depressions of the heart, as well as the papillary muscles and their tendons, and the valves. It consists of three layers; an epithelium, an elastic layer on which the varying thickness of the endocardium in dif-

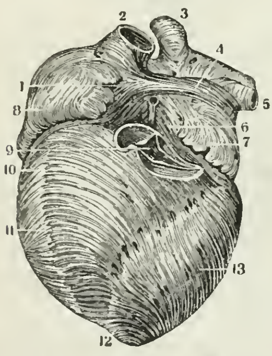
[1] Valentin, Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.

ferent situations depends, and a thin layer of connective tissue.[1] M. Deschamps[2] has described a membrane, which is situate between the endocardium and the areolar tissue that lines the muscular structure at its inner surface, and belongs essentially to the elastic fibrous tissue.

The tissue of the heart is supplied with blood by the *cardiac* or *coronary arteries*—the first division of the aorta; and their blood is conveyed back to the right auricle by the *coronary veins.* The nerves, which follow the ramifications of the coronary arteries, proceed chiefly from a plexus, formed by the spinal nerves and great sympathetic. Besides the large ganglia on the cardiac plexuses at the base of the organ, the nerves present minute ganglia along their course in its substance;[3] and Dr. Robert Lee[4] has affirmed, that it can be clearly demonstrated, that every artery distributed throughout the walls of the heart, and every muscular fasciculus of the organ, is supplied with nerves upon which ganglia are formed. The results of Dr. Lee's observations, are not, however, considered by all to be established.[5]

In both hearts, the auricles are much thinner and more capacious than the ventricles; but they are themselves much alike in structure

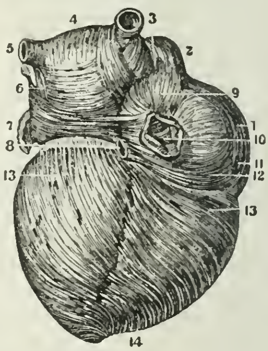
Fig. 98.



Anterior View of External Muscular Layer of the Heart after removal of its Serous Coat, &c.

1. Right auricle. 2. Descending vena cava. 3. Right anterior pulmonary vein. 4. Horizontal band of fibres passing across the base of the auricles 5. Left anterior pulmonary vein. 6. Muscular fibres between auricles. 7. Fringed or ring-shaped bands of fibres at the extremity of left auricle. 8. Muscular fibres at the base of right auricle. 9. Section of pulmonary artery, showing semilunar valves. 10, 11. Anterior bis-ventricular muscular fibres. 12, 13. Their continuation on to left ventricle.

Fig. 99.



Posterior View of the same.

1. Right auricle. 2. Descending vena cava. 3. Right posterior pulmonary vein. 4. Muscular fibres of left auricle. 5. Left posterior pulmonary vein. 6, 7. Arrangement of muscular fibres at the end of left auricle. 8. Orifice of great coronary vein. 9. Band of fibres between the two venæ cavæ. 10. Orifice of the ascending vena cava; Eustachian valve is at the end of the line. 11, 12. Muscular fibres at the base of auricle. 13, 14. Muscular fibres in the ventricles.

and size. The observation, that the right ventricle is larger than the left, is as old as Hippocrates, and has been attempted to be accounted for in various ways. Some have ascribed it to original conformation;

[1] Kölliker, Mikroskopische Anatomie, 2ter Band, s. 492, Leipzig, 1854; and Amer. edit. of his Manual of Human Histology, by Dr. Da Costa, p. 669, Philad., 1854.

[2] Gazette Médicale de Paris, No. 10, and Encyclographie des Sciences Médicales, Avril, 1840, p. 281.

[3] Remak, Kölliker, op. cit.

[4] Philosophical Transactions, Part i. for 1849.

[5] British and Foreign Medico-Chirurgical Review, p. 550, Oct. 1849.

others to the blood being cooled in its passage through the lung, and therefore occupying a smaller space when it reaches the left side of the heart. Haller[1] and Meckel[2] assert, that it is dependent upon the kind of death; that if the right ventricle be usually more capacious, it is owing to the lung being one of the organs that yields first, thus occasioning accumulation of blood in the right cavities of the heart; and they state that they succeeded, in their experiments, in rendering either one or the other of the ventricles more capacious, according as the cause of death arrested first the circulation in the lung or in the aorta; but the experiments of Legallois[3] and Seiler,[4] especially of the former, upon dogs, cats, Guinea pigs, rabbits, the adult, the child, and the stillborn fœtus, with mercury poured into the cavities, have shown that, except in the fœtus, the right ventricle is more capacious, whether death has been produced by suffocation, in which the blood is accumulated in the right side of the heart, or by hemorrhage; and Legallois[5] thinks, that the difference is owing to the left ventricle being more muscular, and, therefore, returning more upon itself. The capacity of each of the ventricles in the full-sized heart has been estimated at about two fluid ounces;[6] but by Valentin[7] at more than double, and by Volkmann more than treble that amount.

The two hearts, united together by a median septum, form, then, one organ, which is situate in the middle of the chest, (see Fig. 79,) between the lungs, and, consequently, in the most fixed part of the thorax. Figure 100 is modified from one carefully made from nature by Dr. Pennock.[8] It represents the normal position of the heart and great vessels.

According to Carus,[9] the weight of the heart compared with that of the body is as 1 to 160. M. J. Weber[10] found the proportion, in one case, to be 1 to 150; Dr. Clendinning[11] that of the male to be 1 to 160; that of the female 1 to 150; and Laënnec considered the organ to be of a healthy size when equal to the fist of the individual. M. Cruveilhier estimates the mean weight at six or seven ounces. M. Bouillaud[12] weighed the hearts of thirteen subjects, in whom, from the general habit, previous state of health, and mode of death, there was every reason to believe that they were in the natural state. The mean was eight ounces and three drachms. From all his data he is led to fix the average weight of the heart, in the adult, from the 25th to the 60th year, at from 8 to 9 ounces. Dr. Clendinning carefully examined nearly four hundred hearts of persons of both sexes, and of all ages

[1] Element. Physiol., iv. 3, 3.

[2] Handbuch der Menschlichen Anatomie, Halle, 1817, s. 46; or the translation from the French version, by Dr. Doane, Philad., 1832.

[3] Dict. des Sciences Médicales, v. 440.

[4] Art. Herz. in Pierer's Anat. Physiol. Real Wörterb., iv. 32, Leipz., 1821.

[5] Œuvres, Paris, 1824.

[6] Quain and Sharpey's edit. of Quain's Human Anatomy, Amer. edit., by Leidy, ii. 487, Philad., 1849.

[7] Lehrbuch der Physiologie des Menschen, i. 415.

[8] Medical Examiner, April 4, 1840.

[9] Introduction to Comp. Anat., translated by R. T. Gore, Lond., 1827.

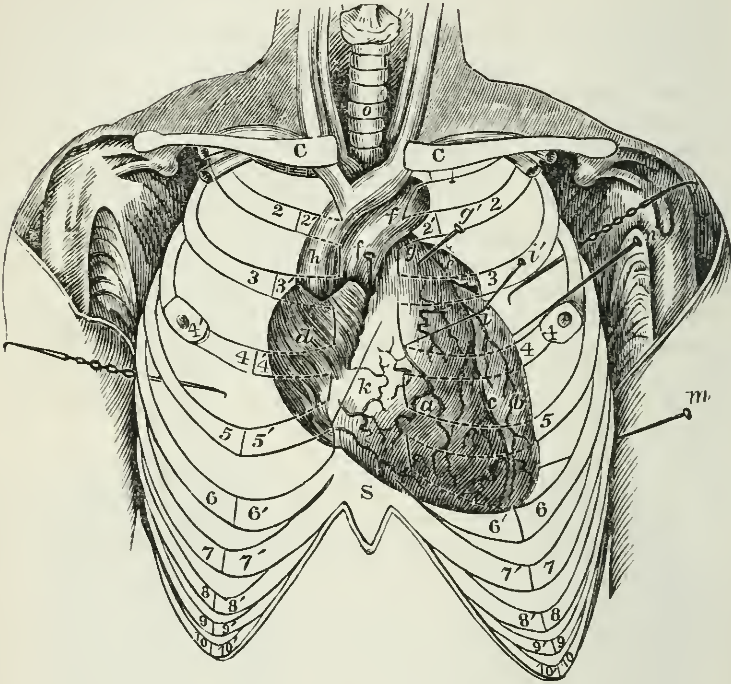
[10] Hildebrandt's Handbuch der Anatomie, von E. H. Weber, Braunschweig, 1831, Band. iii. s. 125.

[11] Journal of the Statistical Society of London, July, 1838.

[12] Traité Clinique des Maladies du Cœur, &c., Paris, 1835.

above puberty. The average weight was about nine ounces avoirdupois,—much less than that observed by Dr. John Reid,[1] who found

Fig. 100.



View of the Heart in situ.

S. Outline of sternum. C, C. Clavicles. 1, 2, 3, 4, 5, 6, &c. Ribs. 1′, 2′, 3′, 4′, 5′, 6′, &c. Cartilages of ribs. 4′. Right and left nipples. *a*. Right ventricle. *b*. Left ventricle. *c*. Septum between ventricles. *d*. Right auricle. *e*. Left auricle. *f*. Aorta. *f′*. Needle passing through aortic valves. *g*. Pulmonary artery. *g′*. Needle passing through valves of pulmonary artery. *h*. Vena cava descendens. *i*. Line of direction of mitral valve; dotted portion posterior to the right ventricle. *i*. Needle passed into mitral valve at its extreme left. *k*. Line of tricuspid valve. *o*. Trachea.

the average weight of the male heart—of 89 weighed—to be 11 oz. and 1 dr.: and of the female heart—of 53 weighed—to be 9 oz. and ½ dr. The weight and dimensions of the organ, according to Lobstein and Bouillaud, are as follows:—Weight, 9 to 10 ounces; length from base to apex, 5 inches 6 lines; breadth at the base, 3 inches; thickness of walls of left ventricle, 7 lines; do. at a finger's breadth above the apex, 4 lines; thickness of walls of right ventricle, 2¼ lines; do. at apex, ½ a line; thickness of right auricle, 1 line; do. of left auricle, ½ a line. M. Bizot[2] has given the following measurements, taking the average of males from 16 to 89 years.

	Base.	Middle.	Apex.
Left ventricle	4½ lines	5⅙	3¾
Right ventricle	$1\frac{15}{16}$	1⅜	$1\frac{1}{30}$

[1] Lond. and Edinb. Monthly Journal of Med. Science, April, 1843, p. 322.

[2] For the results of M. Bizot's researches, to ascertain the dimensions of the heart and arteries, see Mémoires de la Société Médicale d'Observation, Paris, 1837; and Hope on the Diseases of the Heart, Amer. edit., by Dr. Pennock, p. 234, Philad., 1842.

In the female, the average thickness is something less. Dr. Ranking[1] has published the results of measurements, evidently made with accuracy, of upwards of 100 hearts,—care being taken to exclude all those that exhibited any trace of organic change. The following are the *mean* admeasurements. Of 15 male hearts, the mean *circumference* was $9\frac{27}{48}$ths inches; of 17 female hearts, $8\frac{16}{48}$ths inches. The mean *length* of the male heart was $4\frac{16}{48}$ths inches; of the female, $4\frac{36}{48}$ths. The mean *thickness* of the left ventricle, in the male, was $\frac{27}{48}$ths of an inch; in the female, $\frac{23}{48}$ths; of the right ventricle, in the male, $\frac{8}{48}$ths; in the female, $\frac{6}{48}$ths. The septum ventriculorum has, in the male, a mean thickness of $\frac{22}{48}$ths of an inch; in the female, $\frac{14}{48}$ths. The aortic orifice, in the male, had a mean circumference of $2\frac{34}{48}$ths inches; the right auriculo-ventricular orifice, $4\frac{35}{48}$ths inches; the left auriculo-ventricular orifice, $3\frac{45}{48}$ths inches. The corresponding parts of the female were relatively less. Dr. Ranking infers, that the heart of the male is larger than that of the female,—that the length of the healthy heart is to its circumference rather less than 1 to 2,—that the thickness of the parietes of the right ventricle to the left is as 1 to 3 nearly:—that the pulmonary artery is slightly wider than the aorta; and, lastly, that the right auriculo-ventricular opening is considerably larger than the left.

It need scarcely be said, that the weight and dimensions of the organ must vary according to the age, sex, &c., of the individual. M. Bizot[2] found, that the influence of stature on its size was slight; and not such as might have been expected *à priori;* for, in individuals of the male sex above sixty inches, and in females above fifty-five inches, in height, the mean dimensions of the organ, especially its breadth, were less than in persons of a lower stature. He found the width of the shoulders furnish a better proportionate standard of its measurement,—the distance between the acromial point of the clavicles, and the length and breadth of the heart increasing in a tolerably regular ratio. Numerous measurements of the organ have been made on children by MM. Rilliet and Barthez;[3] whence it results: *First.* That its circumference does not augment in proportion to age. It is nearly the same from 15 months to five years and a half; and from the latter age it goes on increasing irregularly until puberty. *Secondly.* The distance from the base to the apex is nearly one-half the total circumference at the base of the ventricles. *Thirdly.* The maximum thickness of the parietes of the right ventricle varies but little according to age. It is generally 0·078 Eng. inch to the age of six years; and after this from 0·118 to 0·157. *Fourthly.* The maximum thickness of the left ventricle remains below 0·393 Eng. inch, until six years of age. Later, it is habitually 0·393, or a little more. *Fifthly.* The proportion between the thickness of the two ventricles is generally, as stated by M. Guersant, as 3 to 1, or 4 to 1, rather more than less. *Sixthly.* The maximum thickness of the septum is nearly the same as that of the left ventricle, a little more rather than less. *Seventhly.* The seat of the maximum thickness of the right ven-

[1] London Medical Gazette, No. xxiv., 1842.

[2] Mémoires de la Société Médicale d'Observation de Paris, tom. 1ère, Paris, 1836.

[3] Traité Clinique et Pratique des Maladies des Enfants, iii. 662, Paris, 1843.

tricle is at the base, and near the auriculo-ventricular orifice; that of the left ventricle one or two centimètres (in. 0·393 or 0·796) from the base; and that of the septum from two to three centimètres (in. 0.796 to 1·171). *Eighthly.* The size of the right auriculo-ventricular orifice remains nearly the same until the age of 5 years; it scarcely increases in size up to the age of 10; but then augments more manifestly. *Ninthly.* The left auriculo-ventricular orifice, which is always smaller than the right, increases a little more regularly than it with age, and frequently has the same dimensions as the distance from the base of the heart to its apex. *Tenthly.* The aortic orifice presents but a slight augmentation from 15 months to 13 years of age. *Eleventhly.* The pulmonary artery, on the other hand, increases notably from the age of six years to eight, so that although before this period it is equal to or scarcely greater than the aortic orifice, afterwards it is commonly much larger. They did not find any marked difference between the male and female heart in children.

The heart is surrounded by its proper capsule, called *pericardium*,—a fibro-serous membrane, composed of two layers. The outermost of these is fibrous, semi-transparent, and inelastic; strongly resembling the dura mater in its texture. Its thickness is greater at the sides than below, where it rests upon the diaphragm; or than above, where it passes along the great vessels which communicate with the heart. The inner layer is of a serous character, and lines the outer, giving the polish to its cardiac surface; it is then reflected over the heart, and adheres to it by areolar substance. Like other serous membranes, it secretes a fluid, termed *liquor pericardii*, to lubricate the surface of the heart. This fluid is always found in greater or less quantity after death; and a question has arisen as to the amount that should be considered morbid. This must obviously vary according to circumstances. In the healthy condition, it is seldom above a tea-spoonful. When its quantity is augmented, the disease *hydropericardium* exists. Its great use probably is to keep the heart constantly moist by the exhalation effected from it; and, also, to restrain the movements of the organ, which, under the influence of the emotions, sometimes leaps inordinately. If the pericardium be divided in a living animal, the heart is found to bound, as it were, from its ordinary position; and hence the expression,—" leaping of the heart,"—during emotion, is physiologically accurate.

b. *Arteries.*

Arteries are solid, elastic tubes, which arise, by a single trunk, from the ventricle of each heart, and gradually divide and subdivide, until they are lost in the capillary system. The large artery, which arises from the left ventricle, and conducts the blood to every part of the body,—even to the lungs, so far as regards their nutrition,—is the *aorta;* and that, which arises from the right ventricle and conveys venous blood to the lungs for aeration, is the *pulmonary artery.* Neither the one nor the other is the continuation of the proper tissue of the ventricles; the inner membrane is alone continuous—the muscular structure of the heart being united to the fibrous coat of the arteries by means of an intermediate fibrous tissue. The *aorta*, as soon as it quits the left ventricle, passes beneath the pulmonary artery, is entirely concealed by it, and ascends to form a curvature with the convexity upwards, the summit of which rises to within three quarters of an inch or an inch of the superior edge of the sternum. This great curvature is called the *cross* or *arch of the aorta.* The vessel then passes downwards, from the top of the thorax to nearly as far as the sacrum, where it divides into two trunks, one of which proceeds to each lower extremity. In the whole of this course, it lies close to the spine, and gives off the various branches that convey arterial blood to the different parts of the body. Of the immense multitude of these ramifications an idea may be formed, when we reflect, that the finest pointed needle cannot be run into any part of the surface of the body, without blood—probably both arterial and venous—flowing. The larger arteries are situate deeply; and are thus remote from external injury. They communicate freely with each other, and their anastomoses are more frequent as the arteries become smaller and farther from the heart. At their final terminations, they communicate with the veins and lymphatics.

It has been a common, but questionable belief, that the branches of the aorta, when taken collectively, are of much greater capacity than the parent trunk, and that this excess goes on augmenting; so that the ultimate divisions of an artery are of much greater capacity than the parent trunk. Hence, the arterial system has been considered to represent, in the aggregate, a cone, whose apex is at the heart, and base in the organs; but as all the minute arterial ramifications are not visible, it is obviously impracticable to discover the ratio between their united capacity and that of the aorta at its origin: yet the problem has been attempted. Keill, by experiments made on an injected subject, considered it to be as 44,507 to 1:—J. C. A. Helvetius and Sylva as 500 to 1. Sénac estimated, not their capacities but their diameters, and conceived the ratio of these to be as 118,490 to 90,000; and George Martine affirmed, that the calibre of a parent arterial trunk is equal to the cube root of the united diameters of the branches.[1] It will be shown, however, hereafter, from the observations of M. Poiseuille and Mr. Ferneley, that the notion of the much greater capacity of the branches than of the parent trunk is a fallacy. The whole subject will be referred to in another place.

The *pulmonary artery* strongly resembles the aorta. Its distribution has been already described as a part of the respiratory organs.

The *arteries* are composed of different coats in superposition, respecting the number of which anatomists have not been entirely of accord. Some have admitted six; others five; others four; but at the present day, three only are perhaps generally received;—first, an *external, areolar* or *cellular*, called also *nervous*, and *cartilaginous* by Vesalius, and *tendinous* by Heister, which is formed of condensed areolar substance, and has considerable strength and elasticity, so that if a ligature be applied tightly round the vessel, the middle and internal coats may be completely cut through, whilst the outer coat may remain entire. Scarpa is not disposed to admit this as one of the coats. He considers

[1] Haller, Element. Physiolog., lib. ii., sect. 1, § 18, Lausan., 1757.

it only an exterior envelope, to retain the vessel *in situ*. The next coat is the *middle*, *muscular* or *proper* coat, the character of which has been the subject of much discussion. It was, at one time, almost universally believed to be muscular. Such was the opinion of Mr. Hunter.[1] Henle[2] advances the opinion, that its structure is intermediate between areolar and muscular tissue; its microscopic elements being broad and very flat, slightly granulated fibres or bands, which lie in rings around the internal membrane, and are about 0·003 lines in diameter. These with a system or network of dark streaks constitute the middle coat. In the large arteries, as the aorta and its main branches, nearly the whole thickness of this coat is composed of yellow elastic tissue—the *tissu jaune* of the French anatomists: few muscular fibres are perceptible; but in the smaller arteries the proportionate thickness of the elastic coat gradually diminishes; whilst, as a general rule, the muscular fibres increase in number, and form a layer within the elastic coat. Kölliker,[3] indeed, affirms, that the middle tunic of the small arteries is purely muscular, without the slightest admixture of connective tissue and elastic elements. The muscular fibres resemble those of the intestinal tube, being of the nonstriped or nonstriated variety. They are arranged areolarly; are pale and flat, and mingled with filaments of fine elastic tissue.

Nysten,[4] Magendie,[5] and Müller[6] applied the galvanic stimulus to the middle coat, which is the most sensible test of irritability, but without effect. It is proper, however, to remark, that the heart seems equally unsusceptible of the galvanic stimulus; or at least is not affected by it like the voluntary muscles. In the cases of two executed criminals, which the author had an opportunity of observing, although all degrees of galvanism were applied half an hour after the drop fell, no motion whatever was perceptible; yet the voluntary muscles contracted, and continued to do so for an hour and a half after execution. The same fact is recorded in the galvanic experiments of Dr. Ure, detailed in another part of this work, and is attested by Bichat, Treviranus and others. Humboldt, Pfaff, J. F. Meckel, Wedemeyer, and J. Müller, however, affirm the contrary. The last observer states,[7] that with a single pair of plates he excited contractions not only in a frog's heart, which had ceased to beat, but also in that of a dog, under similar circumstances. Into the subject of the cause of the heart's action, we shall, however, inquire presently. Müller[8] suggests, that in the capability to contract under the influence of cold, as exhibited in the experiments of Schwann, referred to hereafter, the contractile tissue of the arteries resembles that of the dartos,

[1] On the Blood, Inflammation and Gunshot Wounds; by Palmer, Amer. edit., p. 156, Philad., 1840.

[2] Casper's Wochenschrift, May 23, 1840, cited in Brit. and For. Med. Rev., Oct. 1840, p. 551.

[3] Mikroskopische Anatomie, 2ter Bd. s. 507, Leipz., 1854; or his Manual of Histology, Sydenham Society edit., Lond., 1854; or Da Costa's Amer. edit. of the same, p. 679, Philad., 1854.

[4] Recherches de Physiologie, &c., p. 325, Paris, 1811.

[5] Précis, 2de édit., ii. 387, Paris. 1825.

[6] Handbuch der Physiologie, Baly's translation, p. 205, Lond., 1838.

[7] Loc. cit.

[8] Archiv. fur 1836, in Lond. Med. Gaz., May, 1837.

and that found in many parts of the skin, as about the nipple and follicles, although the physical characters of the latter are so different from elastic tissue. The *third* or *inner coat* is smooth and polished, and a continuation of the membrane that lines the ventricles. It has an epithelial lining, resembles the serous membranes, and is lubricated by a form of serous exhalation.[1]

The arteries receive the constituents that belong to every living part, —arteries, veins, lymphatics, and nerves. These arteries do not proceed from the vessels they nourish, but from adjacent trunks, as we have remarked of the *vasa vasorum*, to which class they really belong. The nerves proceed from the great sympathetic; form plexuses around the vessels, and accompany them through all their ramifications. By some anatomists, the arteries of the head, neck, thorax, and abdomen, are conceived to be supplied from the great sympathetic, whilst those of the extremities are supplied from the nerves of the spinal marrow. It is probable, however, that more accurate discrimination might trace the dispersion of twigs of the nerves of involuntary motion on all these vessels. The organization of the arteries renders them tough and extremely elastic, both of which qualities are necessary to enable them to withstand the impulse of the blood sent from the heart, and to react upon the fluid so as to influence its course. It is by virtue of this structure, that the parietes retain their form in the dead body,—one of the points that distinguish them from the veins.

The vitality of the arteries is inconsiderable. Hence their diseases are by no means numerous or frequent,—an important fact, seeing that their functions are essential, and their activity incessant.

c. *Intermediate, Peripheral or Capillary System.*

The capillary or intermediate vessels are of extreme minuteness, and are by some considered to be formed by the terminations of arteries and the commencement of veins; by others to be a distinct set of vessels. This system forms a plexus which is distributed over every part of the body, and constitutes, in the aggregate, what is meant by the *capillary system.* It admits of two great divisions, one situate at the termination of the branches given off from the aorta, and called the *general capillary system;* the other at the termination of the branches of the pulmonary artery,—the *pulmonic capillary system.* Although the capillary system of man does not admit of detection by the unaided sight, its existence is evidenced by the microscope; by injections, which develope it artificially in almost every organ; by the application of excitants, and by inflammation. The parietes frequently cannot be distinguished from the substance of the tissues;—the colour of the blood, or the matter of the injection alone indicating their course. In some parts, as in the white textures, these vessels do not seem to admit the red particles of the blood, whilst others admit them always. This diversity gave rise to a distinction of the capillaries into *red* and *white;* but there are probably none of the latter. It is difficult, indeed, to

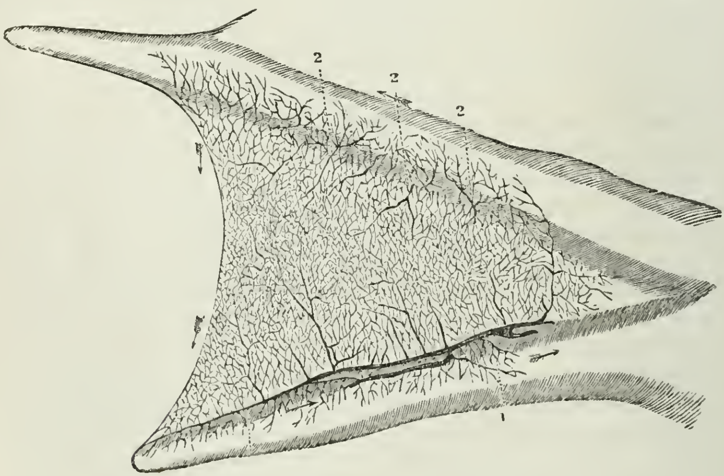
[1] For some speculations as to the agency of this secretion in the production of the buffy state of the blood, &c., see M. Romain Gerardin, in Journal des Connaissances Médico-Chirurgicales, Mars, 1836.

conceive how the red particles could be arrested at the mouths of the white arteries—if such existed—without their preventing altogether the entrance of blood into them. The true cause of the whiteness appears to be the small quantity of blood they receive; and it is only when the network is very close, and the quantity of blood passing through them great, that a perceptible colour is produced. If a plate of red glass be reduced to a very thin pellicle, and be placed between the eye and light, its colour will be scarcely sensible. To perceive it, several of these pellicles must be placed over each other, and they must be examined not by their transparency, but by causing the light to fall on their surface, or by reflection.

There are certain textures, again, which receive no bloodvessels,—the corneous and epidermic, for example. They are probably nourished by transudation of nutritive matter from the vessels of the surrounding tissue.

The ancients were of opinion, that arteries and veins are separated by an intermediate substance, consisting of a fluid effused from the blood, which they called, in consequence, *parenchyma*.[1] The notion is, indeed, still entertained; and is considered to be supported by microscopical observations. In the examination of delicate and transparent tissues, currents of moving globules are seen with many spaces of apparently solid substances, resembling small islets, surrounded by an agitated fluid. If the tissue be irritated by thrusting a fine needle into

Fig. 101.



Circulation in the Web of the Frog's Foot.

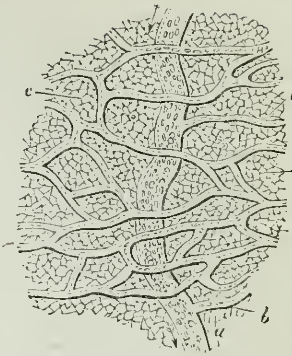
1, 1. Veins. 2, 2. Arteries.

it, the motion of the globules becomes more rapid; new currents arise where none were previously perceptible, and the whole becomes a mass of moving particles, the general direction of which tends towards the points of irritation. But although a part of the apparatus of inter-

[1] Galen. Administrat. Anatom., vi. 2.

mediate circulation may be arranged, in this manner, there are reasons for the belief, that a more direct communication between the arteries and veins exists also. The substance of an injection passes from one set of vessels into the other, without any evidence of intermediate extravasation. The blood has been seen, too, passing in living animals, directly from the arteries into the veins. Leeuenhoek[1] and Malpighi,[2] on examining the swim-bladders, gills, and tails of fishes, the mesentery of frogs, &c.—which are transparent,—observed this distinctly; and the fact has been proved by the observations of Cowper, Cheselden, Hales, Spallanzani, Thomson, Cuvier, Configliachi, Rusconi, Döllinger, Carus, and others.

Fig. 102.



Portion of the Web of the Frog's Foot.

a. A deeper lying venous trunk, with which two smaller capillary veins, *b, b*, communicate. *c, c.* The angular unnucleated cells of the parenchyma.

Fig. 103.

Circulation in the Under Surface of the Tongue of the Frog.

x, x. Venous branches uniting to form a principal vein, *y*. *z, z.* Follicles into which a small artery enters, which becomes convoluted before issuing from them. A beautiful capillary rete, and some muscular fibres are also seen.

The artery and vein terminate in two different ways;—at times, after the former has become extremely minute, by sending off numerous

[1] Select Works, containing his Microscopical Discoveries, by Samuel Hooke, p. 90, Lond., 1778.

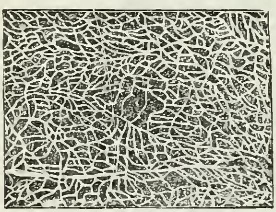
[2] Epist. de Pulmonibus, 1661, and Haller, Element. Physiol., lib. iii. sect. 3, § 20, Lausann., 1757.

lateral branches, as Haller states he noticed in the swim bladders of fishes; at others, by proceeding parallel to each other, and communicating by a multitude of transverse branches. Fig. 101 exhibits a microscopic view of the membrane between two of the toes of the hind foot of the frog, *Rana esculenta*, magnified three diameters.

Fig. 102 shows a portion of the web of a frog's foot magnified 45 diameters. The superficial network of capillaries is seen admitting but a single series of blood particles. All the vessels, here figured, are, according to Wagner,[1] furnished with distinct parietes.

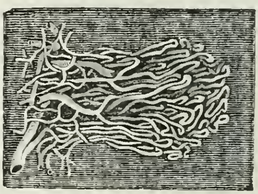
Fig. 103 is a beautiful representation of the circulation in the under surface of the tongue. Along the larger vessels the blood can be seen rushing with excessive velocity. It is proper, however, to state that the more the parts are magnified, the greater will be the apparent velocity. The mean real velocity, Valentin[2] thinks, is one-eighth less in the capillaries than in the veins and arteries.[3] These larger vessels have distinct coats; but single files of globules are seen proceeding slowly through channels to which the author has not been able to satisfy himself that there were distinct parietes. The tongue of the frog offers by far the most satisfactory opportunity for distinctly witnessing the circulation; a fact for the knowledge of which the author is indebted to M. Donné.[4]

Fig. 104.



Capillary Network of Nervous Centres.

Fig. 105.



Capillary Network of Fungiform Papilla of the Tongue.

The capillary vessels have been esteemed by some to belong chiefly to the arteries, the venous radicles not arising almost imperceptibly from the capillary system, as the arteries terminate in it, but having a marked size at the part where they quit this system, which strikingly contrasts with the excessive tenuity of the capillary arterial vessels; whilst between the capillary system and the arteries there is no distinct line of demarcation. The opinion of Bichat[5] was, that this system is entirely independent of both arteries and veins; and Autenrieth[6] imagined, that the minute arteries unite to form trunks, which again divide before communicating with the veins, so as to represent a system analogous to that of the vena porta. The experiments of Dr. Marshall

[1] Elements of Physiology, by R. Willis, Lond., 1842.
[2] Lehrbuch der Physiologie des Menschen, i. 467, Braunschweig, 1844.
[3] See also Lebert, Physiologie Pathologique, i. 7, Paris, 1845.
[4] Cours de Microscopie, p. 109, Paris, 1844; and Atlas, planche vi., Paris, 1845.
[5] Anatomie Générale, &c., édit. de MM. Blandin et Magendie, ii. 299, Paris, 1832.
[6] Physiologie, ii. 138.

Hall[1] on the batrachia, which were performed with signal care, led him to the following conclusions, which agree with those of Bichat, so far as regards the independent existence of a capillary system. The minute vessels, he says, may be considered arterial, so long as they continue to divide and subdivide into smaller and smaller branches. The minute veins are the vessels that gradually enlarge from the successive addition of small roots. The true capillary vessels are distinct from these. They do not become smaller by subdivision, or larger by conjunction, but are characterized by continual and successive union and division or anastomoses, whilst they retain a nearly uniform diameter. The last branches of the arterial system, and the first root of the venous, Dr. Hall remarks, may be denominated minute, but the term "capillary" must be reserved for, and appropriated to, vessels of a distinct character and order, and of an intermediate station, carrying red globules, and perfectly visible by means of the microscope.

Of late, M. Bourgery[2] has maintained, that besides the intermediate vessels, which form the direct communication between the arteries and veins, there is a special capillary arrangement in every tissue by which the functions of nutrition and secretion are accomplished. The diameter of these capillaries, according to M. Bourgery, is not more than one-half, one-third, or even one-fourth of that of the blood corpuscles; and they can, consequently, convey only liquor sanguinis. But the existence of these vessels is not considered to be demonstrated; whilst their absence in tissues—as cartilage—which they were formerly supposed to penetrate, has been established.[3]

The capillary arteries are distinct in structure—as they are in office—from the larger arteries. All the coats diminish in thickness and strength, as the tubes lessen in size; but this is more especially the case with the middle coat, which, according to Wedemeyer, may still be distinguished by its colour in the transverse section of any vessel whose calibre is not less than the tenth of a line; but entirely disappears in vessels too small to receive the wave of blood in a manifest jet. While the coats diminish, the nervous filaments, distributed to them, increase; the smaller and thinner the capillary, the greater the proportionate quantity of its nervous matter. The coats of the capillaries become successively thinner and thinner, and at length disappear altogether; and the vessels—many of them at least—seem to terminate in membraneless canals or interstitial passages, formed in the substance of the tissues. The blood is contained—according to Wedemeyer, Gruithuisen, Döllinger, Carus, and others—in the different tissues in channels, which it forms in them: even under the microscope, the stream is seen to work out for itself, easily and rapidly, a new passage in the tissues, and it is esteemed certain, that in the figura venosa of the egg, the blood is not surrounded by vascular parietes. Most histologists of the day are disposed, however, to believe, that the capillaries are provided with distinct coats. Such, as has been seen, appeared to Wagner to be the case in the frog's foot,

[1] A Critical and Experimental Essay on the Circulation, &c., Lond., 1830; Amer. edit., Philad., 1835.

[2] Comptes Rendus, &c., 1848, and Gazette Médicale, No. 37, 1848.

[3] British and Foreign Médico-Chirurgical Review, p. 527, Oct., 1848.

when magnified 45 diameters; and it has even been announced, that they are composed of a fibrous structure, analogous to the muscular.

Fig. 106.

Capillaries of the Web of the Frog's Foot.

1. Deep venous trunk, composed of three principal branches, 2, 2, 2; and covered with a rete of smaller vessels.

Fig. 106, from Wagner, exhibits the vascular rete and circulation of the web of the hind foot of a frog—*Rana temporaria*—magnified 110 times: here the parietes are very distinct. In another figure in Wagner, which represents a portion of a live newt, magnified 150 diameters, the capillaries are exceedingly delicate, and their walls by no means as distinct. The arterial and venous trunks and the capillaries that form the medium of communication between them are well seen, as well as the islets of the substance of the lung, in which a granular or areolar texture is indistinctly perceptible. Dr. Carpenter[1] is of opinion, that the mode of origin of the capillaries refutes the supposition, that they are mere passages channeled out of the tissues through which they convey the blood. He thinks there can be no doubt, that they are produced, in any newly forming tissue, not by the retirement of the cells, one from the other, so as to leave passages between them, but by the formation of communications among certain cells, whose cavities become connected with each other, so as to constitute a plexus of tubes, of which the original cell-walls become the parietes.

Of the minute capillaries,—the diameter of which, in parts finely injected, varies from the $\frac{1}{1000}$th to the $\frac{1}{4000}$th, and the $\frac{1}{5000}$th of an inch and even more,—some, according to Wedemeyer, communicate

[1] Human Physiology, § 477, Lond., 1842.

with veins; in others, there are no visible openings or pores in the sides or ends, by which the blood can be extravasated preparatory to its being imbibed by the veins. There is nowhere apparent a sudden passage of the arterial into the venous stream; no abrupt boundary between the division of the two systems. The arterial streamlet winds through long routes before it assumes the nature, and takes the direction, of a venous streamlet. The ultimate capillary rarely passes from a large arterial into a large venous branch. Many speculations have been indulged regarding the mode in which the vascular extremities of the capillary system are arranged. Bichat regarded it as a vast reservoir, whence originate, besides veins, vessels of a particular order, whose office it is to pour out, by their free extremity, the materials of nutrition,—vessels, which had been previously imagined by Boerhaave, and are commonly known under the appellation of *exhalants.* Mascagni[1] supposed that the final arterial terminations are pierced, towards their point of junction with the veins, by lateral pores, through which the secreted matters transude;—but these points will farther engage attention under Nutrition and Secretion.

d. *Veins.*

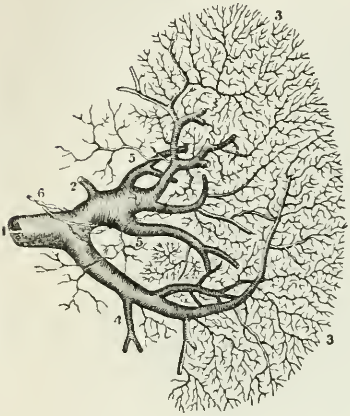
The origin of the veins, like that of all capillary vessels, is imperceptible. By some they are regarded as continuous with the capillary arteries; Malpighi[2] and Leeuenhoek[3] state this as the result of their microscopic observations on living animals; and it has been inferred, from the facility with which an injection passes from the arteries into the veins. According to others, cells exist between the arterial and the venous capillaries, in which the former deposit their fluid contents, and whence the latter obtain it. Others, again, substitute a spongy tissue for the cells. It has also been asked,—whether there may not be more delicate vessels communicating with their radicles, similar to the exhalants which are presumed to exist at the extremities of the arteries, and which are regarded as the agents of exhalation. All this is, however, conjectural. It has already been observed, that the mesenteric veins have been supposed by some to terminate by open mouths in the villi of the intestines; and the same arrangement has been conceived to prevail with regard to other veins; but there is no evidence of this. M. Ribes concludes, from the results of injecting the veins, that some of the venous capillaries are immediately continuous with the minute arteries, whilst others open into the cells of the areolar tissue, and into the substance of different organs.

When the veins become visible, they appear as an infinite number of extremely small tubes communicating very freely with each other; so as to form a very fine network. These vessels gradually become larger and less numerous, but still preserve their reticular arrangement; until, ultimately, all the veins of the body empty themselves into the heart by three trunks—the *vena cava inferior*, *vena cava superior*, and *coronary vein.* The *first* of these receives the veins from the lower part of the

[1] Vasor. Lymph. Corpor. Human. Histor., Sen. 1817; and Prodromo della Grande Anatomie, Firenz., 1819.
[2] Secunda Epistola de Pulmonibus, Opera, Lond., 1687.
[3] Epistol. 59, Opera, Lugd. Bat., 1722.

body, and extends from the fourth lumbar vertebra to the right auricle; the *second* receives all those of the upper part of the body. It extends from the cartilage of the first rib to the right auricle. The coronary vein belongs to the heart exclusively; between the superior and inferior cava a communication is formed by means of the vena azygos.

Fig. 107.



Splenic Vein with its Branches and Ramifications.

1. Trunk of the vein. 2. Gastric branch of this vein coming from the stomach. 3. Branches coming from the substance of the spleen. 4. Small mesenteric vein cut off. 5. Branches coming from external coat of the spleen. 6. Branches of lymphatic vessels of spleen.

Certain organs, as the spleen, appear to be almost wholly composed of venous radicles. Fig. 107 represents the ramifications of the splenic vein, in the substance of that organ; and if we consider, that the splenic artery has corresponding ramifications, the viscus would seem to be almost wholly formed of bloodvessels. The same may be said of the corpus cavernosum of the penis and clitoris, nipple, urethra, glans penis, &c. If an injection be thrown into one of the veins that issue from these different tissues, they are filled by the injection; this rarely occurs, if the injection be forced into the artery. M. Magendie[1] affirms, that the communication of the cavernous tissue of the penis with the veins occurs through apertures two or three millimètres—in. 0·117—in diameter.

In their course towards the heart, particularly in the extremities, the veins are divided into two planes;—one subcutaneous or superficial; the other deep-seated, and accompanying the deep-seated arteries. Numerous anastomoses occur between these, especially when the veins become small, or are more distant from the heart. We find, that their disposition differs according to the organ. In the brain, they constitute, in great part, the pia mater; and enter the ventricles, where they contribute to the formation of the plexus choroides and tela choroidea. On leaving the organ we find them situate between the laminæ of the dura mater; when they take the name of *sinuses*. In the spermatic cord, they are extremely tortuous; anastomose repeatedly, and form the *corpus pampiniforme;* around the vagina, they constitute the *corpus retiforme;* in the uterus, the *uterine sinuses.* They have three coats in superposition, according to most anatomists; but many modern anatomists are disposed to assign them six. The *outer coat* is areolar; dense, and very difficult to rupture. The *middle coat* has been termed the *proper membrane* of the veins. The generality of anatomists describe it as composed of longitudinal fibres, which are more distinct in the vena cava inferior than in the vena cava superior; in the superficial veins than in the deep-seated; in the branches than

[1] Précis, &c., ii. 238.

in the trunks. M. Magendie[1] states, that he has never been able to observe the fibres of the middle coat; but has always seen a multitude of filaments interlacing in all directions; and assuming the appearance of longitudinal fibres, when the vein is folded or wrinkled longitudinally, which is frequently the case in the large veins. It exhibited to him no signs of muscularity; even when the galvanic stimulus was applied; yet M. Magendie suspected its chemical nature to be fibrinous. It was remarked, in an early part of this volume,[2] that the bases of the areolar and muscular tissue are, respectively, gelatin, and fibrin; and that the various resisting solids may all be brought to one or other of those tissues. The middle coat of the veins doubtless belongs essentially to the former, and is a variety of the *tissu jaune* of the French anatomists. M. Magendie merely states its fibrinous nature to be a suspicion; and, like numerous suspicions, this may be devoid of foundation. Yet we have reason to believe, that it is contractile; and, of late,[3] it has been described as formed of one or two or even more layers between the external and internal coats; these layers consisting of fibres, which agree, in all respects, with the white areolar tissue; and are either quite pure, or mixed in one or other of the layers with a greater or less amount of fibres, resembling those of the middle coat of the arteries in having the anatomical characters of the nonstriated or unstriped muscular fibres. The muscular fibre-cells are, however, much fewer in number, and are sometimes wanting. Kölliker[4] says they do not exist in the uterine portion of the placenta, the veins of the cerebral substance and pia mater; the sinuses of the dura mater; the veins of the bones; the venous sinuses of the corpora cavernosa of the male and female; and probably in those of the spleen. M. Broussais[5] affirms, that the contraction of the middle coat is one of the principal causes of the return of the blood to the heart. He conceives, that the alternate movements of contraction and relaxation are altogether similar to those of the heart; but that they are so slight as not to have been rendered perceptible in the majority of the veins, although they are very visible in the vena cava of frogs, where it joins the right auricle. In some experiments by M. Sarlandière on the circulation, he observed these movements to be independent of those of the heart. After the organ was removed, and even after blood had ceased to flow,[6] the contraction and relaxation of the vein continued for many minutes in the cut extremity; and it has been elsewhere remarked, that Mr. Wharton Jones had discovered in the veins of the bat's wing a regular rhythmical contraction and dilatation.

The *inner coat* is extremely thin and smooth at its inner surface, and has an epithelial lining. It is very extensible, and yet presents considerable resistance; bearing a very tight ligature without being ruptured. In many of the veins, parabolic folds of the inner coat exist,

[1] Op. cit., ii. 242. See on the researches of histologists, Mr. Paget, Brit. and For. Med. Review, July, 1842, ii. 242.

[2] Page 59.

[3] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Leidy, i. 518, Philad., 1849.

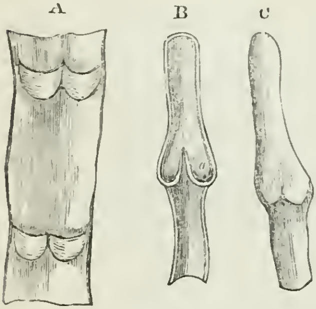
[4] Manual of Human Histology, Amer. edit., by Dr. Da Costa, p. 689, Philad., 1854.

[5] Op. citat., American translation, p. 391.

[6] See, on this subject, the remarks on the Circulation in the Veins.

like those in the lymphatics, which are inservient to a similar purpose; the free edge of these *valves* is directed towards the centre of the circulation, showing that their office is to permit the blood to flow in that direction, and prevent its retrogression. They do not seem, however, in many cases, well adapted for the purpose; inasmuch as their size is insufficient to obliterate the cavity of the vein. By most anatomists, this arrangement is considered to depend upon primary organization; but Bichat conceives it to be wholly owing to the state of contraction, or dilatation of the veins, at the moment of death. M. Magendie affirms, that he has never seen the distension of the veins exert any influence on the size of the valves; but that their shape is somewhat modified by the state of contraction or dilatation; and this he thinks probably misled Bichat.[1] Moreover, they are covered by the epithelial coat and consist of tissue like that of fibrous membrane, which, as Mr. Hunter[2] observed, shows, that they are not duplicatures of the lining membrane. Their number varies in different veins. As a general rule, they are more numerous, where the blood proceeds against its gravity, or where the veins are very extensible, and receive but a feeble support from the circumambient parts, as in the extremities. They are entirely wanting in the veins of the deep-seated viscera; in those of the brain and spinal marrow, and of the lungs; in the vena porta, and in the veins of the kidneys, bladder, and uterus. They exist, however, in the spermatic veins; and, sometimes, in the internal mammary, and in the branches of the vena azygos. On the cardiac side of these valves, cavities or sinuses exist, which appear externally in the form of varices. These dilatations enable the refluent blood to catch the free edges of the valves, and thus depress them, so as to close the cavity of the vessel; serving, in this respect, precisely the same functions as the sinuses of the pulmonary artery and aorta serve in regard to the semilunar valves. The valves exist in veins of less than a line in diameter.

Fig. 108.



Diagrams showing Valves of Veins.

A. Part of a vein laid open and spread out, with two pairs of valves. B. Longitudinal section of a vein, showing the apposition of the edges of the valves in their closed state. C. Portion of a distended vein, exhibiting a swelling in the situation of a pair of valves.

The three coats united form a solid vessel,—which, according to Bichat, is devoid of elasticity, but in the opinion of M. Magendie[3] is elastic in an eminent degree. The elasticity is certainly much less than in the arteries. The veins are nourished by *vasa vasorum*, or by small arteries, that have their accompanying veins. Every vessel, indeed, in the body, if we may judge from analogy, draws its nutriment, not from the blood circulating in it, but from small arterial vessels, hence termed *vasa vasorum*. This applies not only to the veins, but to the arteries. The heart, for example, is not nourished by the fluid con-

[1] Précis, &c., ii. 241.
[2] Treatise on the Blood, &c., by Palmer, Amer. edit., p. 216, Philad., 1840.
[3] Précis, &c., ii. 243.

stantly passing through it; but by vessels, which arise from the aorta, and are distributed over its surface, and in its intimate texture. The coronary arteries and their corresponding veins are, consequently, the *vasa vasorum* of the heart. In like manner, the aorta and all its branches, as well as the veins, receive their vasa vasorum. There must, however, be a term to this; and if our powers of observation were sufficient we ought to be able to discover a vessel, that must derive its support or nourishment exclusively from its own stores.

The nerves that have been detected on the veins are branches of the great sympathetic.

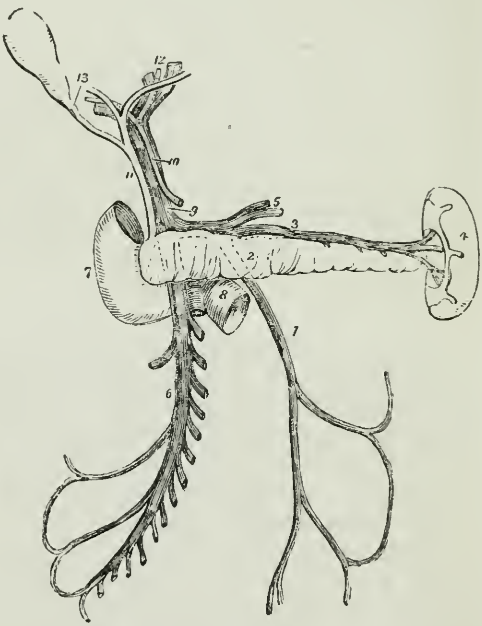
The capacity of the venous system is generally esteemed to be double that of the arterial. It is obvious, however, that we can only arrive

Fig. 109.

Roots, Trunk, and Divisions of the Vena Porta.

1, 1. Veins coming from intestines. 2. Trunk of vena porta. 3, 3. Branches distributed in the liver.

Fig. 110.



Portal System.

1. Inferior mesenteric vein: traced by means of dotted lines behind the pancreas (2) to terminate in splenic vein (3). 4. Spleen. 5. Gastric veins, opening into splenic vein. 6. Superior mesenteric vein. 7. Descending portion of duodenum. 8. Its transverse portion which is crossed by superior mesenteric vein and by a part of trunk of superior mesenteric artery. 9. Portal vein. 10. Hepatic artery. 11. Ductus communis choledochus. 12. Divisions of duct and vessels at transverse fissure of liver. 13. Cystic duct leading to gall-bladder.

at an approximation, and that not a very close one. The size and number of the veins are usually so much greater than those of the corresponding arteries, that when the vessels of a membranous part are injected, the veins are observed to form a plexus, and, in a great measure, to conceal the arteries; in the intestines, the number is more nearly equal. The difficulty of arriving at any exact conclusion regarding the relative capacities of the two systems is forcibly indicated by the fact, that whilst Borelli conceived the preponderance in favour of the veins to be as four to one, Sauvages estimated it at nine to four; Haller at sixteen to nine; and Keill at twenty-five to nine.[1] The ratio between the capacity of individual arteries and veins is very different in different parts. Between the carotid and internal jugular it is as 196 to 441; the subclavian artery and vein, 3844 to 7396; the aorta and venæ cavæ, 9 to 16; and between the splenic artery and vein, 136 to 676.

There is one portion of the venous system, to which allusion has already been made, that is peculiar;—the *abdominal venous* or *portal system*. All the veins, that return from the digestive organs situate in the abdomen unite into a large trunk called *vena porta*. This, instead of passing into a larger vein—into the vena cava, for example—proceeds to the liver, and ramifies, like an artery, in its substance. From the liver other veins, called *supra-hepatic*, arise, which empty themselves into the vena cava; and correspond to the branches of the hepatic artery as well as to those of the vena porta. The portal system is concerned only with the veins of the digestive organs situate in the abdomen; as the spleen, pancreas, stomach, intestines, and omenta. The veins of all the other abdominal organs,—of the kidney, suprarenal capsules, &c., are not connected with it. The first part of the vena portæ is called, by some authors, *vena porta abdominalis* seu *ventralis* to distinguish it from the hepatic portion, which is of great size, and has been called *sinus* of the vena porta.

2. BLOOD.

It is not easy to ascertain the total quantity of blood circulating in both arteries and veins. Many attempts have been instituted for this purpose, but the statements are most diversified, partly owing to the erroneous direction followed by experimenters, but, still more, to the variation that must be perpetually occurring in the amount of fluid, according to age, sex, temperament, activity of secretion, &c. Harvey and the earlier experimenters formed their estimates by opening the veins and arteries freely on a living animal, collecting the blood that flowed, and comparing this with the weight of the body. The plan is, however, objectionable, as the whole of the blood can never be obtained in this manner, and the proportion discharged varies in different animals and circumstances. By this method, Moulins found the proportion in a sheep to be $\frac{1}{23}$d; King, in a lamb, $\frac{1}{20}$th; in a duck, $\frac{1}{30}$th; and in a rabbit $\frac{1}{30}$th. From these and other observations, Harvey concluded, that the weight of the blood of an animal is to that of the whole animal as 1 to 20. Drélincourt, however, found the proportion in a hog to be nearly $\frac{1}{10}$th; and Moor, $\frac{1}{12}$th.[2] Sir George Lefevre[3] cites from Wrisberg, that from a plethoric young woman, who was beheaded, 25 pounds [?] of blood were collected; and some recent experiments by Mr. Wanner[4] led to the following results: A bullock, weighing 1659 pounds imperial, yielded 69 pounds of blood,

[1] Elementa Physiologiæ, lib. ii., sect. 2, § 10, Lausann., 1757.
[2] Haller, op. cit., lib. v. sect. 1, § 2.
[3] An Apology for the Nerves, p. 30, London, 1844.
[4] Edinburgh Med. and Surg. Journ., July, 1845.

or in the ratio of 1 to 23·81; another weighing 1640 pounds, yielded 65 pounds, or in the ratio of 1 to 23·73; a cow, weighing 1293 pounds, yielded 59 pounds, or as 1 to 21·77; a sheep, weighing 110 pounds, yielded $5\frac{1}{2}$ pounds, or in the proportion of 1 to 22·72; another weighing 88 pounds, yielded 4·4 pounds, or as 1 to 20; and in a rabbit, the proportion was as 1 to 25 exactly.

An animal, according to Sir Astley Cooper,[1] generally expires, as soon as blood, equal to about $\frac{1}{16}$th of the weight of the body, is abstracted. Thus, if it weighs sixteen ounces, the loss of an ounce of blood will be sufficient to destroy it; and, on examining the body, blood will still be found—in the small vessels especially—even although every facility may have been afforded for draining them. Experiments have, however, shown that no fixed proportion of the circulating fluid can be indicated as necessary for the maintenance of life. In the experiments of Rosa, asphyxia occurred in young calves when from three to six pounds, or from $\frac{1}{32}$d to $\frac{1}{20}$th of their weight, had been abstracted; but in older ones not until they had lost from twelve to sixteen pounds, or from $\frac{1}{11}$th to $\frac{1}{9}$th of their weight. In a lamb, asphyxia supervened on a loss of twenty-eight ounces, or $\frac{1}{28}$th of its weight; and in a wether, on a loss of sixty-one ounces, or $\frac{1}{23}$d of its weight. Dr. Blundell[2] found that some dogs died after losing nine ounces, or $\frac{1}{30}$th of their weight; whilst others withstood the abstraction of a pound, or $\frac{1}{16}$th of their weight; and M. Piorry affirms, that dogs can bear the loss of $\frac{1}{25}$th of their weight, but if a few ounces more be drawn they succumb. From all the experiments and observations, Burdach[3] concludes, that, on the average, death occurs when $\frac{3}{4}$ths, or $\frac{7}{8}$ths, of the mass of blood is lost, although he has observed it in many cases, as in hæmoptysis, on the loss of $\frac{1}{4}$th, and even of $\frac{1}{8}$th.

The following table exhibits the computations of different physiologists regarding the weight of the circulating fluid—arterial and venous.

	lbs.		lbs.
Harvey, Lister, Moulins, Abildguard,	8	Weber and Lehmann,	$17\frac{1}{2}$ to 19
Blumenbach, Lobb, Lower,	10	Müller, Burdach and P. Bérard,	20
Sprengel,	10 to 15	Wagner,	20 to 25
Günther and Bock,	15 to 20	Quesnai,	27
		F. Hoffmann,	28
		Haller,	28 to 30
		Young,	40
		Hamberger,	80
		Keill,	100

Although the absolute estimate of Hoffmann has been regarded as below the truth, the proportion has seemed to many to be nearly accurate; but it is evidently too high. He conceives, that the weight of the blood is to that of the whole body as 1 to 5. Accordingly, an individual weighing one hundred and fifty pounds, will have about thirty pounds of blood; one of two hundred pounds, forty; and so on. Of this, one-third is supposed to be contained in the arteries, and two-thirds in the veins. The estimate of Haller[4] is, perhaps, near the

[1] Principles and Practice of Surgery, p. 33, Lee's edition, Lond., 1836.
[2] Researches, Physiological and Pathological, pp. 66 and 94, Lond., 1825.
[3] Die Physiologie als Erfahrungswissenschaft, iv. 101 and 334, Leipzig, 1832.
[4] Op. cit., lib. v., sect. 1, § 3.

truth; the arterial blood being, he conceives, to the venous, as 4 to 9. Were we, therefore, to assume with Hoffmann that the whole quantity of the blood is thirty pounds in a man weighing one hundred and fifty pounds, which is, however, allowing too much,—nine pounds, at at least, may be contained in the arteries, and the remainder in the veins.

An ingenious plan, proposed by Valentin[1] for estimating the quantity of blood in the body, affords an approximation to the truth, and is confirmatory of the estimate made from other data. Having weighed an animal, and determined the proportion of solid matter in a portion of its blood, he injects into its vessels a given quantity of distilled water, which soon becomes mixed with the blood. He then takes away a fresh portion of blood, and ascertains the proportion of solid matter in it. The relation between the amount of solid matter in the blood first taken, and that in the blood diluted with the given quantity of water, enables him to calculate the quantity of blood in the body of the animal. The following question and solution are given, in order to show, how the quantity of blood may be estimated in the manner proposed by Valentin.

A portion of blood (= 1190 grains), drawn from a dog, yielded 24·54 per cent. of solid matter. After injecting 10,905 grains of water into the bloodvessels, a portion of blood drawn yielded 21·86 (or, by another trial, 21·89) per cent. of solid matter. What was the amount of blood in the body at the commencement of the experiment?

Let x be the amount of blood *after* the first experiment. Then, since it contained 24·54 per cent. of solid residue, the amount of solid matter in it was ·2454 x. After injecting the water the whole amount of the diluted blood was $x + 10905$; and (by the experiment) the solid matter which it contained was = ·2186 $(x + 10905)$. But the solid matter was of the same amount in both cases. Therefore we have,

$$\cdot 2454\, x = \cdot 2186\ (x + 10905)$$

or, $$(\cdot 2454 - \cdot 2186)\ x = \cdot 2186 \times 10905$$

or, $$x = \frac{2383\cdot 8330}{\cdot 0268} = 88945 \text{ grs.}$$

Add for the blood first drawn 1190

And we get . . . . 90135 grs.

the weight of blood in the body at the commencement of the experiment.

The ratio 21·89 per cent. gives . . . . 91269 grs.

And the mean of the two is . . . . . 90702 "

In this manner, Valentin found the ratio of blood to the weight of the body to be in the dog as 1 to 4·36 in the male sex, and 1 to 4·93 in the female; and adapting these proportions to M. Quetelet's table of the weight of the human subject at different ages, he infers, that the mean quantity of blood in the male adult, at the time when the weight of the body may be presumed to be greatest, namely at 30 years, should be about 34½ pounds; and that of the female at 50, when the weight is generally greatest, at about 26 pounds. It is difficult, however, to be-

[1] Lehrbuch der Physiologie des Menschen, i. 490, Braunschweig, 1844.

lieve, that there is not some fallacy in these calculations. The proportion of blood to the rest of the body, judging from the quantity that has usually flowed from animals bled to death, and the apparent quantity remaining in the vessels, seems to be excessive; and such is the view of Professor Blake of Saint Louis. In a letter to the author, he refers to experiments instituted by him, which consisted in injecting a weighed quantity of sulphate of alumina into the veins, and analyzing a weighed portion of the blood. As the salt had time to be well mixed with the blood before the animal died, such an analysis, he conceived, would enable the whole quantity of blood with which the salt had been mixed to be determined. The only error which—it appeared to him—might arise would be from a portion of the salt having combined with some of the tissues, or having been rapidly excreted, which could only affect the result in one direction, viz. in furnishing a greater quantity of blood than really exists. The results led Dr. Blake to infer, that there was no such source of error, as he found by this method, that the weight of blood in the body of a dog does not amount to more than between one-eighth or one-ninth part of the weight of the animal, a ratio much lower—as has been shown—than is generally conceived. "That this, however, is nearer the truth is probable from the consideration of the velocity of the circulation and the capacity of the heart, as, on the generally received opinion of the quantity of the blood, it is difficult to imagine how it can circulate so rapidly."[1] This estimate would give the quantity of blood in a man weighing 150 pounds from 16½ lbs. to 18¾—not very far from the estimates of Günther[2], Bock,[3] and of Weber and Lehmann,[4] who determined the weights of two criminals both before and after their decapitation. The quantity of blood which escaped from the body was estimated in the following manner. Water was injected into the vessels of the trunk and head, until the fluid escaping from the veins had only a pale red or yellow colour: the quantity of blood remaining in the body was then calculated, by instituting a comparison between the solid residue of the pale-red aqueous fluid and that of the blood which first escaped. They found the weight of the whole of the blood was to that of the body nearly in the proportion of 1 to 8. More recently, Welcker has estimated it as 1 to 10.[5]

The blood strongly resembles the chyle in properties;—the great difference consisting in the colour. The venous blood, the chyle, and the lymph become equally converted into the same fluid—arterial blood—in the lungs: both the chyle and lymph may, indeed, be regarded as rudimental blood.

Venous blood, which chiefly concerns us at present, is contained in all

[1] Medical Examiner, August, 1849, p. 459.

[2] Lehrbuch der Physiologie des Menschen, 2ter Band, 1ste Abtheilung, S. 122, Leipzig, 1848.

[3] Lehrbuch der pathologischen Anatomie, 3te Auflage, S. 275, Leipzig, 1852.

[4] Lehrbuch der physiologischen Chemie, ii. 259, Leipzig, 1850; or Amer. edit., by Dr. R. E. Rogers, i. 638, Philad., 1855; and R. Wagner's Lehrbuch der speciellen Physiologie, von Funke, 1ste Lieferung, S. 4, Leipzig, 1854.

[5] Prager Vierteljahrschrift, iv. 11; and Canstatt's Jahresbericht, 1854, i. 44, Würzburg, 1855.

the veins, in the right side of the heart, and in the pulmonary artery;—organs which constitute the apparatus of venous circulation. As drawn from the arm its appearance is familiar to every one. At first, it seems to be entirely homogeneous; but, after resting for some time, separates into different portions. The colour of venous blood is much darker than that of arterial; so dark, indeed, as to have led to the epithet *black blood* applied to it. Its smell is faint and peculiar; by some compared to a fragrant garlic odour, but *sui generis;* its taste is slightly saline, and also peculiar. It is viscid to the touch; coagulable; and its temperature has been estimated at 96° Fahrenheit; simply, we believe, on the authority of the inventor of the thermometric scale, who marked 96° as blood heat. This is too low by at least three or four degrees. Rudolphi,[1] and the German writers in general, estimate it at 29° of Réaumur, or "from 98° to 100° of Fahrenheit;" whilst, by the French writers in general, its mean temperature is stated at 31° of Réaumur, or 102° of Fahrenheit; M. Magendie,[2] who is usually very accurate, fixes the temperature of venous blood at 31° of Réaumur, or 102° of Fahrenheit; and that of arterial blood at 32° of Réaumur, or 104° of Fahrenheit. 100° may perhaps be taken as the average. This was the natural temperature of the stomach in the case related by Dr. Beaumont,[3] which has been so often referred to in these pages. In many animals, the temperature is considerably higher. In the sheep it is 102° or 103°; but it is most elevated in birds. In the duck it is 107°. On this subject, however, further information will be given under the head of CALORIFICATION.

The specific gravity of blood is differently estimated by different observers. Hence it is probable, that it varies in individuals, and in the same individual at different periods. Compared with water, the mean has been estimated, by some, to be as 1·0527; by others, as 1·0800, to 1·0000. It is stated, however, to have been found as high as 1·126; and, in disease, as low as 1·022. It has, moreover, been conceived, that the effect of disease is, invariably, to make it lighter; and that the more healthy the individual, the greater is its specific gravity; but our information on this point is vague. That it is not always the same in health is proved by the discrepancy of observers. Boyle estimated it to be 1·041; Martine, 1.045; Jurin, 1·054; Muschenbroek, 1·056: Denis, 1.059; Sénac, 1·082; Berzelius, from 1·052 to 1·126; J. Müller, from 1·0527 to 1·0570; Mandl, from 1·050 to 1·059; and Dr. G. O. Rees, from 1·057 to 1·060. In a large number of experiments made upon the blood of man, the ox, and horse, M. Simon[4] found it to be between 1·051 and 1·058. The average was 1·042, [1052?] which, he says, corresponds very nearly with the statement of Berzelius. The average of human blood may perhaps be 1·050. Nasse says 1·055; Zimmerman, 1·056. A part of the discrepancy may be owing to the specific gravity not having been always taken at the same temperature. Dr. B. Babington found experimentally that four degrees of temperature corresponded with a differ-

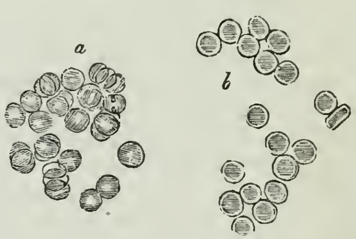
[1] Grundriss der Physiologie, i. 143, Berlin, 1821.
[2] Précis, &c., ii. 229.
[3] Experiments, &c., on the Gastric Juice, &c., p. 274, Plattsburg, 1833.
[4] Animal Chemistry, Sydenham edition, i. 100, Lond., 1845.

ence of ·001 of specific weight; consequently, if one author states the specific gravity of blood at about its circulating temperature—say 98° of Fahr.—while another states it at 60° Fahr.—the usual standard—the former will make it .0095 lighter than the latter.

The blood of man is thicker, and at least one-thousandth heavier than that of woman.

When blood is examined with a microscope of high magnifying power, it is found to be composed of numerous, minute, *red particles* or *corpuscles*,—commonly called *red globules*, *blood corpuscles*, and *blood disks*, —suspended in the serum. These corpuscles have a different shape and dimension, according to the nature of the animal. In the mammalia, they are circular; and, in birds and cold-blooded animals, elliptical. In all animals, they are affirmed, by some observers, to be flattened, and marked in the centre with a luminous point, of a shape analogous to the general shape of the corpuscle. Professor Giacomoni,[1] of Padua, has, however, affirmed, that the red corpuscles swimming in serum,—which have been described, by so many writers, in the circulating fluid, exist only in the imagination. As in most cases that rest on microscopic observation, discrepancy has prevailed, not only as regards the shape, but the size of the corpuscles. These were first noticed by Malpighi;[2] and afterwards more minutely examined by Leeuenhoek, who at first described them correctly enough in general terms; but subsequently became hypothetical; and advanced the fantasy, that the red corpuscles are composed of a series of globular bodies, descending in regular gradations; each of the red corpuscles being composed of six particles of serum; a particle of serum of six particles of lymph, &c. Totally devoid of foundation as the whole notion was, it was believed for a considerable period, even until the time when Haller wrote. Mr. Hewson[3] described the corpuscles as consisting of a solid centre, surrounded by a vesicle, filled with a fluid; and to be "as flat as a guinea." Mr. Hunter,[4] on the other hand, did not regard them as solid bodies, but as liquids possessing a central attraction that determines their shape. Della Torre[5] supposed them to be a kind of disk or ring, pierced in the centre; whilst Dr. Monro conceived them to be circular, flattened bodies, like coins, with a dark spot in the centre, which he thought was not owing to a perforation, as Della Torre had imagined, but to a depression. Cavallo,[6] again, conceived, that all these appear-

Fig. 111.



Red Corpuscles of Human Blood.

Represented at *a*, as they are seen when rather *beyond* the focus of the microscope; and at *b* as they appear when *within* the focus. Magnified 400 diameters.

[1] Encyclogr. des Sciences Médicales, Avril, 1840, p. 529.
[2] Opera, Lond., 1687.
[3] Experimental Inquiries, part. iii. p. 16, Lond., 1777, or Hewson's Works, by Gulliver, Sydenham Society's edit., p. 215, Lond., 1846.
[4] On the Blood, &c., by Palmer, Amer. edit., p. 63, Philad., 1840.
[5] Philos. Trans. for 1765, p. 252.
[6] An Essay on the Medicinal Properties of Factitious Air, &c., p. 237, Lond., 1798.

ances are deceptive, depending upon the peculiar modification of the rays of light, as affected by the form of the particle; and he concluded, that they are simple spheres. Amici found them of two kinds; both with angular margins; but, in the one, the centre was depressed on both sides; whilst, in the other, it was elevated. The observations of Dr. Young,[1] of Sir Everard Home and Mr. Bauer,[2] and of MM. Prévost and Dumas,[3] accord chiefly with those of Mr. Hewson. All these gentlemen consider the red corpuscles to be composed of a central globule, which is transparent and whitish; and of a red envelope, which is less transparent. Dr. Hodgkin and Mr. Lister[4] have denied that they are spherical, and consist of a central nucleus enclosed in a vesicle. They affirm, on the authority of a microscope, which, on comparison, was found equal to a celebrated one, taken a few years ago to Great Britain by Professor Amici,[5] that the particles of human blood consist of circular, flattened, transparent cakes, their thickness being about $\frac{1}{45}$ part of their diameter. These, when seen singly, appear to be nearly or quite colourless. Their edges are rounded, and being the thickest part, occasion a depression in the middle, which exists on both surfaces. The view of these gentlemen, consequently, appears to resemble that of Dr. Monro. Mr. Gulliver,[6] however, thinks that the ratio of 1 to 45, given by Dr. Hodgkin and Mr. Lister, must be a misprint. From measurements of the thickness, at the circumference of the corpuscles of several mammalia, he found it to be generally one-third and one-fourth the diameter: the average thickness of the human blood corpuscle he estimates at $\frac{1}{12400}$th of an English inch, and the diameter at $\frac{1}{3200}$th.

Amidst this discordance, it was difficult to know which view to adopt. The belief in their consisting of circular, flattened, transparent bodies, with a depression in the centre, and of an external envelope and a central nucleus, the former of which is red and gives colour to the blood, has had, perhaps, the greatest weight of authority in its favour. The nucleus has appeared to observers to be devoid of colour, and to be independent of the envelope; as, when the latter was destroyed, the central portion—it was conceived—preserved its original shape. The nucleus was considered to be much smaller than the envelope, being, according to Dr. Young, only about one-third the length, and one-half the breadth of the entire corpuscle. According to Sir Everard Home,[7] the corpuscles, enveloped in the colouring matter, are $\frac{1}{1700}$th part of an inch in diameter, requiring 2,890,000 to a square inch; but deprived of their colouring matter they appear to be $\frac{1}{2000}$th part of an inch in diameter, requiring 4,000,000 corpuscles to a square inch. From these measurements, the corpuscles, when devoid of colouring matter, are not quite one-fifth smaller. The views of MM. Prévost and Dumas, who have investigated the subject with extreme

[1] Introduct. to Med. Literature, p. 545.

[2] Philosoph. Transact. for 1811–1818; and Lectures on Comp. Anat., iii. 4, Lond., 1823.

[3] Annales de Chimie, &c., xxiii. 50, 90; and Journal of Science and Arts, xvi. 115.

[4] Philosoph. Magazine and Annals of Philosophy, ii. 130, Lond., 1827.

[5] Edinb. Medical and Surgical Journal, xvi. 120.

[6] Hewson's Works, Sydenham Society's edit., note to page 215, Lond., 1846.

[7] Lectures on Comparative Anatomy, iii. 4, and v. 100, Lond., 1828.

care and signal ingenuity, are deserving of great attention. They conceive the blood to consist essentially of serum, in which a quantity of red corpuscles is suspended; that each of these corpuscles consists of an external red vesicle, which encloses, in its centre, a colourless globule; that during the progress of coagulation, the vesicle bursts, and permits the central globule to escape; that, on losing their envelope, the central globules are attracted together; that they are disposed to arrange themselves in lines and fibres; that these fibres form a network, in the meshes of which they mechanically entangle a quantity of both the serum and the colouring matter; that these latter substances may be removed by draining, and by ablution in water; that, when this is done, there remains only pure fibrin; and that, consequently, fibrin consists of an aggregation of the central globules of the red corpuscles, while the general mass, that constitutes the crassamentum or clot, is composed of the entire particle. So far this seems satisfactory; but, we have seen, Dr. Hodgkin does not recognise the existence of external vesicle, or central nucleus; and he affirms, contrary to the notion of Sir Everard Home and others, that the particles are disposed to coalesce in their entire state. This is best seen when the blood is viewed between two slips of glass. Under such circumstances, the following appearances are distinctly perceptible. When human blood, or that of any other animal which has circular corpuscles, is examined in this manner, considerable agitation is, at first, seen to take place among the corpuscles; but, as this subsides, they apply themselves to each other by their broad surfaces, and form piles or rouleaux, sometimes of considerable length. These rouleaux often again combine,—the end of one being attached to the side of another,—so as to produce, at times, very curious ramifications.

The fact of the corpuscles being flattened disks is now admitted;—but the form of the disk is found to be altered by various substances. Its external envelope readily admits the endosmose of fluids; so that, if placed in water, it may assume a truly globular shape. In examining the blood, consequently, it is advisable to dilute it with a fluid of as nearly as possible the same character as the serum. In the particles of the blood of the frog—as represented in Fig. 112—a nucleus is observed projecting somewhat from the central portion: this is rendered extremely distinct by the action of acetic acid, which dissolves the rest of the particle, and renders the nucleus more opaque. It then appears to consist of a granular substance. The vesicular character of the red corpuscles was clearly shown by Dr. G. O. Rees,[1] by the readiness with which they become collapsed or distended by increasing or diminishing the specific gravity of the medium in which they float. In order to collapse the corpuscles, a solution of sp. gr. 1·060 is sufficient, but a solution of 1·070 or more is required to produce a decided effect. Solutions cease to distend the corpuscles when of sp. gr. 1·050 to 1·055, and to distend them well a solution of 1·015 or 1·010 is desirable. He, moreover, established, what is now generally admitted, that the red colouring matter of the corpuscle is seated, not in the

[1] Ranking's Half-Yearly Abstract of the Medical Sciences, vol. i., Jan. to June, 1845, p. 250.

envelope, but in the fluid within the vesicle, and that the envelopes themselves are white and colourless membranes. This is shown by increasing the specific gravity of the liquid in which the corpuscles float, the result of which is the escape by exosmose of the red coloured fluid from within the corpuscles; and, again, by applying water to the corpuscles, and inducing endosmose, the vesicles become distended and burst; their colouring matter mixes with the water, and the envelopes subside to the bottom of the vessel, forming a white layer. The red corpuscles of man have no nuclei, and their contents are probably homogeneous. They appear so at least when their surfaces are flat or slightly convex; but when concave the unequal refraction of transmitted light gives the appearance of a central spot, which is brighter or darker than the border according as it is viewed in or out of focus. (See Fig. 111.)

Microscopical discordances are no less evidenced by the estimates, which have been made of the size of the red corpuscles; yet all are adduced on the faith of positive admeasurements. Leaving out of view the older, and, consequently, it might be presumed, less accurate observations, the following table shows their diameter in human blood, on the authority of some of the most eminent microscopic observers of modern times.

Sir E. Home and Mr. Bauer, with colouring matter,	$\frac{1}{1700}$th part of an inch.
Eller,	$\frac{1}{1930}$
Sir E. Home and Mr. Bauer, without colouring matter,	$\frac{1}{2000}$
Müller,	$\frac{1}{2300}$ to $\frac{1}{3500}$
Mandl,	$\frac{1}{2625}$ to $\frac{1}{3150}$
Hodgkin, Lister, and Rudolphi,	$\frac{1}{3000}$
Sprengel,	$\frac{1}{3000}$ to $\frac{1}{3300}$
Cavallo,	$\frac{1}{3000}$ to $\frac{1}{4000}$
Donné,	$\frac{1}{3130}$ to $\frac{1}{3280}$
Jurin and Gulliver,	$\frac{1}{3240}$
Blumenbach and Sénac	$\frac{1}{3330}$
Tabor,	$\frac{1}{3600}$
Milne Edwards,	$\frac{1}{3900}$
Wagner,	$\frac{1}{4000}$
Kater,	$\frac{1}{4000}$ to $\frac{1}{6000}$
Prévost and Dumas,	$\frac{1}{4056}$
Haller, Wollaston and Weber,	$\frac{1}{5000}$
Young,	$\frac{1}{6060}$

The blood of different animals is found to differ greatly in the relative quantity of the red corpuscles it contains, the number seeming to bear a pretty exact ratio with the temperature of the animal. The higher the natural temperature, the greater the proportion of corpuscles; arterial always containing a much greater proportion than venous blood. In the greater part of the mammalia they have the same shape as those of man; but their size varies greatly in different families. It would appear, from the researches of Mandl,[1] that of the mammalia the elephant has the largest, ($\frac{1}{100}$th of a millimètre,) and the ruminantia the smallest; that the family of camels is the only one, whose corpuscles are not round like those of the other mammalia, but

[1] Manuel d'Anatomie Générale, p. 248, Paris, 1843. For numerous admeasurements of the red corpuscles of the blood of man and animals, see Note by Mr. Gulliver to Hewson's Works, Sydenham Society's edit., p. 237, Lond., 1846.

elliptical like those of birds, reptiles, and fishes.[1] In all oviparous vertebrata, without any known exception, the red corpuscles are oval.

Fig. 112.

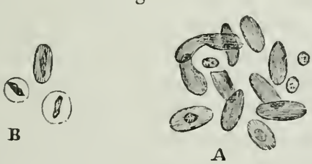
Blood Corpuscles of Rana Esculenta.—Magnified 400 diameters.

1, 1, 1, 2 Blood corpuscles. 2. Seen edgewise. 3. Lymph corpuscle. 4. Altered by dilute acetic acid.

The chemical constitution of the blood corpuscles is not definitely settled. Two proximate principles have been discovered in them—*hematin* or *hematosin*, and *globulin*,—*hematoglobulin* of Simon. The former, as mentioned hereafter, is the colouring matter. The latter, which differs from the globulin of Laënnec,—an impure hematin mingled with some albumen,—is the main constituent of the globules, and is the same as the *blood-casein* of Simon. It has not been separated; but is presumed to differ but little in its properties from protein.

It has been supposed that the red corpuscles are formed originally in the germinal membrane of the embryo: but, throughout the remainder of existence, in the blood from the chyle. Their origin is, however, by no means settled. Normally, they are not found outside the vessels; and are manifestly, therefore, not inservient to nutrition; but connected, in all probability, as shown elsewhere, with respiration

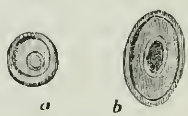
Fig. 113.



Red corpuscles of Pigeon's Blood, magnified 400 diameters.

A. Red particles unaltered, with two or three colourless particles. B. Treated with acetic acid, which develops the cell-wall and nucleus more clearly.

Fig. 114.



Red Corpuscle of Fishes.

a. Lamprey. *b.* Skate.—After Wharton Jones.

and calorification. It is not determined whether they are capable of reproduction, or possess independent life. Dr. Carpenter[2] thinks, that there can be no reasonable doubt, that they are to be regarded as nucleated cells, conformable in general character with the isolated cells that constitute the whole of the simplest plants; having each an independent life, and therefore the power of reproduction. Such too, is the view of Dr. Martin Barry and other microscopists. Wagner, Gulliver, and others,[3] from observation of the blood of the batrachia, ascribe their origin to the colourless corpuscles to be mentioned presently, which, they consider, become red blood corpuscles when fully developed; whilst Dr. Carpenter strenuously maintained, that there is an entire functional as well as structural difference between the red

[1] Op. citat., and Annales des Sciences Naturelles, 1824 and 1825.
[2] Principles of Human Physiology, 2d edit., p. 499, London, 1844.
[3] V. Bruns, Lehrbuch der Allgemeinen Anatomie, s. 140, Braunschweig, 1841.

and the colourless corpuscles of the blood of vertebrata; but since then his views have undergone an entire change.[1] Observations by Dr. G. O. Rees[2] led him to infer, that they multiply by division. On examining a portion of blood, kept at about its natural temperature, he observed the corpuscles assume an hour-glass form, which, increasing, eventually divided each corpuscle into two unequal-sized circular bodies. These, when treated with a strong saline solution, underwent the same exosmotic changes as are observed in common blood corpuscles.

In addition to the red, *white corpuscles* are observed in the blood. These were noticed by Prof. Müller in that of frogs; and by M. Mandl[3] in that of the mammalia. They are small, colourless corpuscles, finely granulated; insoluble in water, and strongly refracting light. According to Mandl, they may be separated into two species,—some round, and containing two or three granules, which become more evident when they are treated with acetic acid: these are the true lymph corpuscles, described already (p. 245); the others, generally also round; sometimes oblong; and at others irregular; the edges slightly notched; and the surface finely granulated. They appear to be composed of a multitude of small molecules, from $\frac{1}{1000}$th to $\frac{1}{1200}$th of a millimètre in diameter: some are also found single. These corpuscles are seen forming under the microscope, when blood, placed between two glasses, is attentively examined. They are, in Mandl's opinion, produced by the coagulation of fibrin, and hence are called by him *fibrinous globules*. More recently, however, he has abandoned this name, "because it rests on a chemical character, that requires confirmation; and because it is not drawn from anatomical characters, which ought chiefly to fix the attention of the microscopist." He now terms them *white granulated corpuscles*.[4] These are the *globulins* of M. Donné, and are considered by him[5] as well as by M. Bernard,[6] to be the first elements of blood corpuscles.

Fig. 115.

White Corpuscles of the Blood.

The white corpuscles are much less numerous than the red. In health the proportion has been stated as 1 to 50; but in disease often as high as 1 to 10.[7] Accurate observations, however, by Welcker[8] and Moleschott[9] make the proportion much smaller. In Welcker's own blood, it was as 1 to 341. Moleschott's observations made it 1 to 357; or about 2·8 parts in the 1000; and Donders and Kölliker[10] appear to agree with him. In certain morbid conditions, especially of the spleen and other vascular glands, an unusual number of colourless corpuscles is observed in the blood; along with a marked diminution of the red

[1] Principles of Human Physiology, Amer. edit., p. 178, Philad., 1855.

[2] Gulstonian Lecture; see Ranking, Half-Yearly Abstract, Jan. and July, 1845, Amer. edit., p. 251.

[3] Gazette Médicale, 1837; and Manuel d'Anatomie Générale, p. 252, Paris, 1843.

[4] Manuel d'Anatomie Générale, p. 554, Paris, 1843.

[5] Cours de Microscopie, p. 86, Paris, 1845.

[6] W. F. Atlee, Notes on M. Bernard's Lectures on the Blood, p. 38, Philad., 1854.

[7] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 52, Philad., 1853.

[8] Prager Vierteljahrschrift, iv. 11, in Canstatt, Jahresbericht, 1854, i. 44 and 165.

[9] Wiener Wochenschrift, No. 8, in Canstatt, op. cit., S. 44.

[10] Mikroskopische Anatomie, ii. 577, Leipzig, 1854; and Manual of Histology, Sydenham Society's edit.; or Amer. edit., by Dr. Da Costa, p. 708, Philad., 1854.

corpuscles, and an increase of the ratio of fibrin. To this condition Professor Bennett, of Edinburgh, gives the name leucocythæmia.[1]

Dr. Barry and Mr. Addison think, that the colourless corpuscles,—which have generally been regarded as lymph corpuscles,—are formed from the central portion of the blood corpuscles: they consider them to hold an intermediate position between the true red corpuscles, and the greatly modified forms of corpuscles, which, in their view, are the basis of the tissues, as well as of pus and other globules. The most probable opinion, however, is that the white corpuscles of the blood are identical with the lymph and chyle corpuscles; and all, in the opinion of Dr. Carpenter,[2] are connected with the elaboration of plastic fibrin, which must be constantly drawn off by the nutritive processes, and therefore require to be reproduced. His arguments on this head are certainly forcible. It was first observed by Wagner,[3] that whilst the colourless corpuscles are met with in the nutritious fluids of all animals that possess a distinct circulation, red corpuscles are restricted to the vertebrata. The truth of this has been confirmed by Dr. Carpenter, who infers from it, that the function of the colourless corpuscles must be of a general character, and intimately connected with the nutritious properties of the circulating fluid; whilst that of the red corpuscles must be of a limited character, being only required in one division of the animal kingdom. One of the strongest arguments, however, in favour of the function of the white corpuscles mentioned above, is the connexion between the generation of white corpuscles in the blood, and the production of fibrin in the inflammatory process. This increase is evidently the result of the local inflammation, and is observed to commence before the occurrence of any constitutional phenomena. The microscopic observations of Messrs. Addison,[4] Williams,[5] Gulliver, and others, have established, that a great accumulation of white corpuscles takes place in the vessels of an inflamed part,—partly owing to an attraction of the corpuscles towards the seat of inflammation, and partly, they were satisfied, by an actual reproduction of fresh corpuscles, which must have been owing either to their own power of generating themselves, or to some change in the blastema or fluid of circulation in the part, which favoured a more abundant production. Dr. Carpenter was a believer in the first mode of production; and certainly his view, that the formation of fibrin in the blood is closely connected with the developement of white corpuscles, had strong arguments in its favour; but he does not now urge that the fibrin is formed by them. Messrs. Kirkes and Paget[6] are firm believers in the developement of the human lymph or chyle corpuscle into the red corpuscle,—a view which appears to be the most philosophical from the phenomena recorded by different observers. Mr. Lane, for example, found the ruddy colour of the horse's chyle due to the presence of red corpuscles; and he and Mr. Ancell observed imperfect blood corpuscles in the large lymphatics, and ascribed

[1] Edinb. Monthly Journ. of Med. Science, for 1851; and his work on Leucocythæmia, Edinb., 1851.

[2] Op. cit., 2d edit., p. 506, Lond., 1844.

[3] Op. cit.

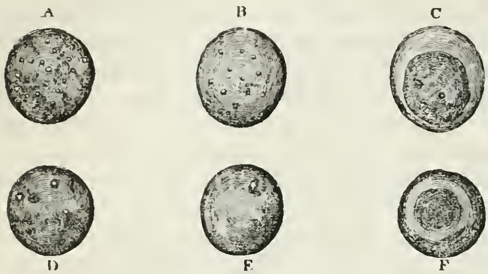
[4] Med. Gazette, Dec., 1840; Jan. and March, 1841.

[5] Principles of Medicine, Amer. edit., by Dr. Clymer, pp. 214, 215, Philad., 1844.

[6] Manual of Physiology, 2d Amer. edit., p. 66, Philad., 1853.

the rose-colour of the lymph to them. The thoracic duct of the horse, according to Mr. Gulliver,[1] often appears as a coloured tube from the number of these corpuscles in the chyle, which he generally found to be smaller, more irregular and less perfect in shape than the red corpuscles in the blood. Schultz and Gurlt[2] also noticed the chyle of a reddish colour from the presence of blood corpuscles, of which they suppose, with Simon of Berlin,[3] the formation to begin in the chyle; and Mr. Gulliver adds, that the transition of the corpuscles of the chyle or lymph into the red corpuscles of the blood, seems now to be commonly admitted in Germany; and, long ago, Mr. Hewson[4] thought "it could not be denied," that the office of the thymus and lymphatic glands is to form the central particles found in the red corpuscles.

Fig. 116.



Developement of Human Lymph and Chyle Corpuscles into Red Corpuscles of Blood.

A. A lymph or white blood-corpuscle. B. The same, in process of conversion into a red corpuscle. C. A lymph corpuscle, with the cell-wall raised up round it by the action of water. D. A lymph corpuscle, from which the granules have almost all disappeared. E. A lymph corpuscle, acquiring colour; a single granule, like a nucleus, remains. F. A red corpuscle, fully developed.

It has been long observed, that crystals might form in blood,[5] but only recently has the subject attracted much attention; and especially since they were depicted, and investigated, by Dr. Otto Funke;[6] who affirmed, that "the organic coloured matters, which form the essential contents of the red corpuscles" can assume, under special circumstances, the crystalline form; and that the contents of the corpuscles, in each kind of blood have a constantly characteristic crystalline form. The essential condition for the crystallization of this *hematocrystallin*, as it has been called by Lehmann,[7] or *hematoidin*, is that it should be freed from the cells. In fishes, however, he has observed it crystallize within the cells. The crystals have a different shape in different animals, and they would seem to be a crystallization of the protein or albuminoid contents of the corpuscles; but nothing definite has as yet been established in regard to them.

When blood is drawn from a vessel, and left to itself, it exhales, so long as it is warm, a fetid vapour consisting of water and animal matter, of a nature not known. This vapour or *halitus* of the blood,—

[1] Appendix to English edition of Gerber's Anatomy, p. 93; and Hewson's Works, Sydenham Society's edit., p. 276, Lond., 1846.

[2] Müller, Elements of Physiology, by Baly, i. 563, Lond., 1838.

[3] Animal Chemistry, Sydenham Society's edit., i. 121, Lond., 1845; or Amer. edit., Philad., 1846.

[4] Works, Sydenham Society's edit., p. 286, Lond., 1846.

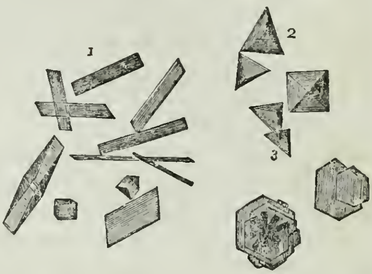
[5] Kölliker, Mikroskopische Anatomie, ii. 587, Leipzig, 1854; or Amer. edit. of his Human Histology by Dr. Da Costa, p. 714, Philad., 1854; and Sieveking on Albuminous Crystallization, in Brit. and For. Med.-Chir. Rev., Oct., 1853, p. 349.

[6] Funke's Wagner's Speciellen Physiologie, s. 20, Leipz., 1854; and Atlas, Taf. x. Fig. 1–6; also, Robin and Verdeil, Traité de Chimie Anatomique, iii. 430, Paris.

[7] Lehmann, Physiological Chemistry, Amer. edit., i. 347, Philad., 1855.

gas animale sanguinis, of Plenck—was conceived by him to be composed of carbon and hydrogen, and to be inservient to many supposititious uses in the economy. The odour exhaled by the blood would appear to have the same general characters under all circumstances. After a time, the blood coagulates, giving off, at the same time, it has been said, a quantity of carbonic acid gas. This disengagement is not evident when the blood is suffered to remain exposed to the air, except, perhaps, by the apertures or canals formed by its passage through the clot; but it can be collected by placing the blood under the receiver of an air-pump, and exhausting the air. On this fact, however, observers do not all accord. The experiments of Vogel,[1] Brande,[2] Sir E. Home,[3] and Sir C. Scudamore,[4] are in favour of such evolution; and the last gentleman conceives it even to be an essential part of the process; but other distinguished experimenters have not been able to detect it. Neither Dr. John Davy,[5] nor Dr. Duncan, Jr., nor Dr. Christison, could procure it during the coagulation of the blood. Dr. Turner[6] suggests, that the appearance of the carbonic acid, in the experiments of Vogel, Brande, and Scudamore, might easily have been occasioned by casual exposure of the blood to the atmosphere, previous to its being placed under the receiver; but we have no reason for believing, that this source of fallacy was not guarded against as much by one set of experimenters as by the other. Our knowledge on this point is confined to the fact, that, by some, carbonic acid gas has been found exhaled during the process of coagulation; by others, not. Experiments by Stromeyer,[7] Gmelin, Tiedemann, and Mitscherlich,[8] would seem to show, that the blood does not give off free carbonic acid, but that it holds a certain quantity in a state of combination; and that this combination is intimate is shown by the fact, mentioned by Müller,[9] that blood, artificially impregnated with carbonic acid, yields no appreciable quantity of the gas, when subjected to the air-pump. Magnus,[10] however, found, in his experiments, that not only venous, but arterial blood, contains carbonic acid, oxygen, and nitrogen; and that, as regards car-

Fig. 117.



Blood Crystals.
1. Prismatic, from human blood. 2. Tetrahedral, from pig's blood. 3. Hexagonal plates, from squirrel's blood.

[1] Annales de Chimie, t. xciii. [2] Philosophical Transactions for 1818, p. 181.
[3] Lectures, &c., iii. 8.
[4] Philosophical Transactions for 1820, p. 6; and an Essay on the Blood, p. 107, Lond., 1824.
[5] Phil. Trans., for 1823, p. 506; and Edinb. Med. and Surg. Journ., xxix. 253. Since that time, however, Dr. Davy has succeeded in extricating it both from venous and arterial blood. See his Researches, Physiological and Anatomical, Amer. Med. Lib. edit., p. 82, Philad., 1840.
[6] Elements of Chemistry, 5th edit., by Dr. Bache, p. 607, Philad., 1835.
[7] Schweigger's Journal für Chemie, u. s. w. lxiv., 105.
[8] Tiedemann und Treviranus, Zeitschrift für Physiologie, B. v. H. i.; cited in British and Foreign Med. Review, No. 9, p. 590, April, 1836. [9] Op. cit., p. 329.
[10] Annales de Chimie et de Physique, Nov., 1837, and page 318, of this volume.

bonic acid, arterial blood contains more than venous; and he accounts for the failure of those, who have attempted to elicit carbonic acid from venous blood by the air-pump, to the air in the receiver not having been sufficiently rarefied. Prof. C. A. Schultz, of Berlin—who believes, that the vesicles of the blood, in a perfect state, are composed of a membranous covering, whose interior is filled with an aeriform fluid in the midst of which is found the nucleus[1]—succeeded in so evident a manner by the following simple method in extracting air from the blood, "that it is impossible to doubt there exists a great quantity of air in the vesicles." He completely filled a bottle with warm blood flowing immediately from the vein of a horse, and hermetically sealed the bottle so that the cork was plunged into the blood, thus absolutely preventing the contact of air. The blood, on cooling, diminished in volume, and thus produced a perfect vacuum in the upper part of the bottle; and in proportion as this took place, bubbles of air arose from the blood and filled the vacuum. Chemical analysis of this air demonstrated that it was carbonic acid. In arterial blood, he found oxygen mixed with more or less carbonic acid.[2] The experiments of Dr. Stevens,[3] and of Dr. Robert E. Rogers,[4] also show, that carbonic acid is contained in the blood. The latter observer found, when a portion of venous blood was placed in a bag of some membrane, and the bag was immersed in an atmosphere of gas—as of oxygen, hydrogen, or nitrogen—that carbonic acid was pretty freely evolved.[5]

Whilst the blood is circulating in the vessels, it consists of *liquor sanguinis* and red corpuscles; but during coagulation it separates into two distinct portions;—a yellowish liquid, called serum; and a red solid, known by the name of *clot*, *cruor*, *crassamentum*, *coagulum*, *placenta*, *insula* and *hepar sanguinis*. The proportion of the serum to the crassamentum varies greatly in different animals, and in the same animal at different times, according to the state of the system. The latter is more abundant in healthy vigorous animals, than in those that have been impoverished by depletion, low living, or disease. Sir Charles Scudamore found, by taking the mean of twelve experiments, that the crassamentum amounted to 53·307 per cent. in healthy blood.

The difference between living and coagulated blood may be expressed in a tabular form as follows:—

Living Blood.	*Liquor Sanguinis,*	Water,	Serum,	Coagulated Blood.
		Various salts,		
		Fatty matters,		
		Extractive do.		
		Albumen,		
		Fibrin.	Crassamentum,	
	Red Corpuscles,			

The *serum* is viscous, transparent, of a slightly yellowish hue, and alkaline owing to the presence of a little free soda. Its smell and taste resemble those of the blood. Its average specific gravity has been

[1] London Lancet, August 10, 1839, p. 713. [2] Ibid., p. 714.

[3] Philos. Transact., for 1834–5, p. 334.

[4] American Journal of the Med. Sciences, August, 1836, p. 283.

[5] See, on all this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., Pt. xxxii. p. 359, Lond., August, 1848.

estimated at about 1·027; but on this point, also, observers differ. Dr. John Davy[1] found it to vary from 1·020 to 1·031. Martine, Muschenbroek, Jurin, and Haller, from 1·022 to 1·037; Berzelius and Wagner,[2] from 1·027 to 1·029; Dr. Christison,[3] from 1·029 to 1·031; Lauer,[4] from 1·009 to 1·011; whilst Mr. Thackrah[5] found the extremes to be 1·004 and 1·080. At 158° of Fahrenheit, it coagulates; forming at the same time, numerous cells, containing a fluid, which oozes out from the coagulum of the serum, and is called *serosity*. It contains, according to Dr. Bostock, about $\frac{1}{50}$th of its weight of animal matter, together with a little chloride of sodium. Of this animal matter, a portion is albumen, which may be readily coagulated by means of galvanism; but a small quantity of some other principle is present, which differs from albumen and gelatin, and to which Dr. Marcet[6] gave the name *muco-extractive matter*, and Dr. Bostock,[7] *uncoagulable matter of the blood*—as a term expressive of its most characteristic property. Serum preserves its property of coagulating, even when largely diluted with water. According to Mr. Brande,[8] it is almost pure liquid albumen, united with soda which keeps it fluid. Consequently, he affirms, any reagent, that takes away the soda, produces coagulation; and by the agency of caloric, the soda may transform a part of the albumen into mucus. The action of the galvanic pile coagulates the serum, and forms globules in it analogous to those of the blood.

From the analysis of serum, by Berzelius,[9] it appears to consist, in 1000 parts;—of water, 903; albumen, 80; substances soluble in alcohol,—as lactate of soda and extractive matter, chlorides of sodium and potassium, 10; substances soluble in water,—as soda and animal matter, and phosphate of soda, 4; loss, 3. Dr. Marcet assigns it the following composition:—water, 900 parts; albumen, 86·8; chlorides of potassium and sodium, 6·6; muco-extractive matter, 4; carbonate of soda, 1·65; sulphate of potassa, 0·35, and earthy phosphates, 0·60;—a result, which closely corresponds with that of Berzelius, who states that the *extractive matter* of Dr. Marcet is lactate of soda, united with animal matter. According to M. Lecanu,[10] 1000 parts contain,—water, 906 parts; albumen, 78; animal matter, soluble in water and alcohol, 1·69; albumen combined with soda, 2·10; crystallizable fatty matter, 1·20; oily matter—*serolin*, 1; chlorides of sodium and potassium, 6; subcarbonate and phosphate of soda, and sulphate of potassa, 2·10; phosphate of lime, magnesia and iron, with subcarbonate of lime and magnesia, 0·91; loss, 1. A more recent analysis by Scherer,[11] gives the following constituents:—

[1] Researches, Physiological and Anatomical, Amer. Med. Lib. edit., p. 11, Philad., 1840.

[2] Elements of Physiology, by R. Willis, § 103, Lond., 1842.

[3] On Granular Degeneration of the Kidneys, p. 61, Lond., 1839; or American Medical Library edition, Philad., 1839.

[4] Hecker's Annalen, xviii. 393.

[5] Inquiry into the Nature and Properties of the Blood, &c., Lond., 1819.

[6] Medico-Chirurg. Transact., ii. 364.

[7] Op. cit., p. 292.

[8] Philosoph. Transact. for 1809, p. 373.

[9] Medico-Chirurg. Transactions, iii. 231.

[10] Journal de Pharmacie, xvii.; and Annales de Chimie, &c., xlviii. 308.

[11] Canstatt and Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, s. 65, Erlangen, 1849.

Water	910·45
Solid parts	89.55
	1000.
Albumen	74·15
Extractive matters	5·96
Salts soluble in water	8·75

Occasionally, the serum presents a whitish hue, which has given rise to the opinion that it contains chyle; but it would seem that this is fatty matter, and is always present. In the serum of the blood of spirit-drinkers, Dr. Traill found a considerable portion, which has been considered to favour the notion, that the human body may, by intemperance, become preternaturally combustible; and has been used to account for some of the strange cases of *spontaneous combustion*, or rather of *preternatural combustibility*, which are on record. Dr. Christison has likewise met with fat mechanically diffused through the serum, like oil in an emulsion. On one occasion, he procured five per cent. of fat from milky serum, and one per cent. from serum which had the aspect of whey.[1]

The *crassamentum* or *clot* is a solid mass, of a reddish-brown colour, which, when gently washed for some time under a small stream of water, separates into two portions,—colouring matter and fibrin. As soon as the blood is drawn from a vessel, the colouring matter of the red corpuscles leaves the central nucleus free; these then unite, as we have seen, and form a network, containing some of the colouring matter, and many whole corpuscles. By washing the clot in cold water, the free colouring matter and the globules can be removed, and the fibrin will alone remain. When freed from the colouring matter, the fibrin is solid, whitish, insipid, inodorous, heavier than water, and without action on vegetable colours; elastic when moist, and becoming brittle by desiccation. It yields, on distillation, much carbonate of ammonia, and a bulky coal, the ashes of which contain a considerable quantity of phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda. One hundred parts of fibrin, according to Berzelius, consist of carbon, 53·360; oxygen, 19·685; hydrogen, 7·021; nitrogen, 19·934. Fibrin has been designated by various names: it is the *gluten*, *coagulable lymph*, and *fibre of the blood*, of different writers. Its specific gravity is said to be greater than that of serum; but the difference has not been accurately estimated, and cannot be great. The red corpuscles are manifestly, however, heavier than either, as we find them subsiding during coagulation to the lower surface of the clot, when the blood has flowed freely from the orifice in the vein. Fibrin is an important constituent of the blood. It exists in animals in which the red corpuscles are absent, and a form of it—syntonin—is the basis of muscular tissue.

The colouring matter of the blood, called, by some, *cruorin*, *hematin*, *hematosin*, *zoo-hematin*, *hemachroin*, *globulin* (of Lecanu), and *rubrin*, has been the subject of anxious investigation with the analytical chemist. It has been already remarked, that it resides in distinct particles or corpuscles, and in the fluid within the enveloping membrane. For-

[1] Edinb. Med. and Surg. Journal, xvii. 235, and xxxiii. 274.

merly, however, the opinion was universal, that the vesicular envelope is the seat of colour. The colouring principle is dissolved, by pure water, acids, alkalies, and alcohol. M. Raspail[1] asserts, that the corpuscles are entirely soluble in pure water, but MM. Donné and Boudet, who repeated his experiments, declare that they are wholly insoluble, and Müller[2] is of the same opinion. Great uncertainty has always existed regarding the cause of the colour of the corpuscles. As soon as the blood was found to contain iron, the peroxide of which has a red hue, their colour was ascribed to the presence of that metal. MM. Fourcroy and Vauquelin[3] held this opinion, conceiving the iron to be in the state of subphosphate; and they affirmed, that if this salt be dissolved in serum by means of an alkali, the colour of the solution is exactly like that of the blood. Berzelius,[4] however, showed, that the subphosphate of iron cannot be dissolved in serum by means of an alkali, except in very minute quantity; and that this salt, even when rendered soluble by phosphoric acid, communicates a tint quite different from that of the red corpuscles. He found, that the ashes of the colouring matter always yield oxide of iron in the proportion of $\frac{1}{200}$th of the original mass; whence it was inferred, that iron is somehow or other concerned in the production of the colour; but the experiments of Berzelius did not indicate the state in which that metal exists in the blood. He could not detect it by any of the liquid tests.

The views of Berzelius, and the experiments on which they were founded, were not supported by the researches of Mr. Brande.[5] He endeavoured to show, that the colour of the blood does not depend upon iron; for he found the indications of the presence of that metal as considerable in the parts of the blood that are devoid of colour, as in the corpuscles themselves; and in each it was present in such small quantity, that no effect, as a colouring agent, could be expected from it. He supposed that the tint of the red corpuscles is produced by a peculiar, animal colouring principle, capable of combining with metallic oxides. He succeeded in obtaining a compound of the colouring matter of the blood with the oxide of tin: but its best precipitants are the nitrate of mercury and corrosive sublimate. Woollen cloths, impregnated with either of these compounds, and dipped in an aqueous solution of the colouring matter, acquire a permanent red dye, unchangeable by washing with soap. The conclusions of Mr. Brande have been supported by M. Vauquelin,[6] but the fact of the presence of iron has been decided by many observers. Engelhart[7] demonstrated, that the fibrin and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron; whilst he procured it from the red corpuscles by incineration. He also succeeded in proving the presence of iron in the colouring matter by liquid tests; for on transmitting a current of chlorine gas through a solution of red corpuscles, the colour entirely disappeared; white flocks were thrown

[1] Chimie Organique, p. 368, Paris, 1833.
[2] Handbuch der Physiologie, Baly's translation, p. 105, Lond., 1838.
[3] System. Chym., ix. 207.
[4] Med.-Chir. Trans., iii. 213.
[5] Philosophical Transactions for 1812, p. 90.
[6] Annales de Chimie et de Physique, tom. i. p. 9.
[7] Edinb. Med. and Surg. Journal, Jan. 1827; and Turner's Chemistry, 5th Amer. edit., p. 605, Philad., 1835.

down, and a transparent solution remained, in which peroxide of iron was discovered by the usual reagents. The results, obtained by Engelhart, as regards the quantity of iron, correspond with those of Berzelius. These facts have since been confirmed by Rose,[1] of Berlin;—and Würzer,[2] of Marburg, by pursuing Engelhart's method by liquid tests, detected the existence of the protoxide of manganese likewise. The proportion of iron does not appear to be more than one-half per cent.; yet, as it is contained only in the colouring matter, there is some reason for believing, that it may be concerned in the coloration of the blood, although probably in the form of oxide. Sulphocyanic acid has been detected in the saliva; and this acid, when united with peroxide of iron, forms a colour exactly like that of venous blood; so that, it has been presumed, it may be connected with the coloration of the blood; but this is not probable; for Dr. Stevens found, that venous blood is darkened by sulphocyanic acid. M. Lecanu[3] has subjected the colouring matter to analysis, and found it to be composed of:—loss, representing the weight of the animal matter, 97·742; subcarbonate of soda, alkaline chlorides, subcarbonates of lime and magnesia, and phosphates of lime and magnesia, 1·724; peroxide of iron, 0·534. The result of his researches induces him to conclude, that the colouring matter is a compound of albumen with some colouring substance unknown. This substance yielded on analysis:—loss, 98·26; peroxide of iron, 1·74; and M. Lecanu suggests, that it may result from the combination of some animal matter with certain ferruginous compounds analogous to cyanides. The views of Liebig in regard to the agency of the iron of the blood in respiration have been given elsewhere.[4]

After all, therefore, our ignorance on this subject is still great; and all that we seem to know is, that peroxide of iron is contained in the colouring matter of the blood; but it can scarcely be the cause of the colour, for Scherer found, that the iron may be wholly dissolved by the agency of acids, and yet the animal matter, boiled afterwards in alcohol, colours the spirit deeply red. Dr. G. O. Rees,[5] however, objects to this being received as a conclusive argument against the iron being essential to the formation of the red colour.

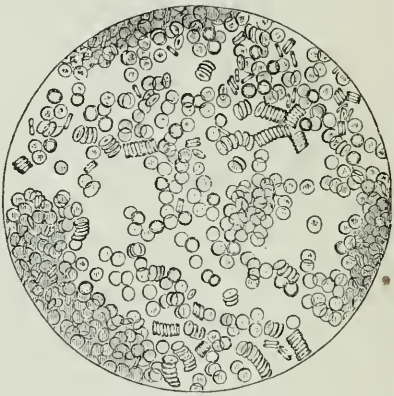
The redness of the blood is one of its most obvious characteristics; and the change effected in the lungs as regards colour has been esteemed of eminent importance. It is no farther so, however, than as it indicates the conversion of venous into arterial blood. There is nothing essential connected with the mere coloration. In the insect, the blood is transparent; in the caterpillar, of a greenish hue; and in the internal vessels of the frog, yellowish. In man, it differs according to numerous circumstances; and the hue of the skin, which is partly dependent upon these differences, thus becomes an index of the state of individual health or disease. In *morbus cæruleus*, *cyanopathy* or *blue disease*, the whole surface is coloured blue, especially in those parts where the

[1] Poggendorf's Annalen, vii. 81; and Annales de Chimie, &c., xxxiv. 268.
[2] Schweigger's Journal, lviii. 481.
[3] Annales de Chimie et de Physique, xlv. 5.
[4] Page 320 of this volume.
[5] Gulstonian Lecture; see Ranking's Abstract, Jan. to July, 1845, p. 251, Amer. edit., New York, 1845.

skin is delicate, as in the lips; and the appearance of the jaundiced is familiar to all.

The formation of the clot, and its separation from the serum, are manifestly dependent upon the fibrin, which, by assuming the solid state, gives rise to the *coagulation* of the blood;—a phenomenon, that has occasioned much fruitless speculation and experiment; yet, if the views of M. Raspail[1] were proved to be correct, it would be sufficiently simple. The alkaline character of the blood, and the production of coagulation by a dilute acid, leave no doubt, in his mind, that an alkali is the menstruum of the albumen of the blood. The alkaline matter, he thinks, is soda, but more especially ammonia, of which, he says, authors take no account; but whose different salts are evident under the microscope. Now, "the carbonic acid of the atmospheric air, and the carbonic acid, that forms in the blood by its avidity for oxygen, saturate the menstruum of the albumen, which is precipitated as a clot. The evaporation of the ammonia, and, above all, the evaporation of the water of the blood, which issues smoking from the vein, likewise set free an additional quantity of dissolved albumen, and the mass coagulates the more quickly as the blood is less aqueous."

Fig. 118.



Coagulation of Normal Human Blood under the Microscope.

The process of coagulation is influenced by exposure to air. Mr. Hewson affirmed, that it is promoted by such exposure, but Mr. Hunter was of an opposite opinion. If the atmospheric air be excluded,—by completely filling a bottle with recently drawn blood, and closing the orifice with a good stopper,—coagulation is retarded. Yet Sir C. Scudamore affirms, that if blood be confined within the exhausted receiver of an air-pump, coagulation is accelerated; and MM. Gmelin, Tiedemann, and Mitscherlich[2] found that, under such circumstances, both venous and arterial blood coagulated as perfectly as usual. The presence of air is certainly not essential to the process. Experiments have also been made on the effect produced by different gases on the process of coagulation; but the results have not been such as to afford much information. It is asserted, for example, by some, that it is promoted by carbonic acid; and certain other irrespirable gases; and retarded by oxygen: by others, the reverse is affirmed: whilst Sir Humphry Davy[3] and Schröder van der Kolk[4] inform us, that they could not

[1] Chimie Organique, p. 373.

[2] Tiedemann and Treviranus, Zeitschrift für Physiol., B. v. Heft i.

[3] Researches, &c., chiefly concerning nitrous oxide, p. 380, Lond., 1800; and Dr. John Davy, Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 48, Philad., 1840.

[4] Dissert. sistens Sang. Coag. Histor., p. 81, Groning., 1820; and Burdach, op. citat., iv. 37.

perceive any difference in the period of the coagulation of venous blood, when it was exposed to nitrogen, nitrous gas, oxygen, nitrous oxide, carbonic acid, hydrocarbon, or atmospheric air.

The time, necessary for coagulation, is affected by temperature. It is promoted by warmth; retarded, but not prevented, by cold. Mr. Hewson froze blood newly drawn from a vein, and afterwards thawed it: it first became fluid, and then coagulated as usual. Hunter made a similar experiment with the like result. It is obviously, therefore, not from simple refrigeration that the blood coagulates. Sir C. Scudamore found, that blood, which begins to coagulate in four minutes and a half, in a temperature of 53° Fahr., undergoes the same change in two minutes and a half at 98°; and that, which coagulates in four minutes at 98° Fahr., becomes solid in one minute at 120°. On the contrary, blood, that coagulates firmly in five minutes at 60° Fahr., remains quite fluid for twenty minutes at the temperature of 40° Fahr., and requires upwards of an hour for complete coagulation. The observations of M. Gendrin[1] were similar. As a general rule, it would seem, from those of Hewson,[2] Schröder van der Kolk,[3] and Thackrah,[4] that coagulation takes place most readily at the temperature of the body. During the coagulation, a quantity of caloric is disengaged. M. Fourcroy[5] relates an experiment, in which the thermometer rose no less than 11° during the process; but as certain experiments of Mr. Hunter[6] appeared to show, that no elevation of temperature occurred, the observation of Fourcroy was disregarded. It was, however, confirmed by experiments of Dr. Gordon,[7] of Edinburgh, in which the evolution of caloric during coagulation was rendered more manifest by moving the thermometer during the formation of the clot, first into the coagulated, and afterwards into the fluid part of the blood: he found, that by this means he could detect a difference of 6°, which continued to be manifested for twenty minutes after the process had commenced. In repeating the experiment on blood taken from a person labouring under inflammatory fever, the thermometer was found to rise 12°. Sir C. Scudamore affirms,[8] that the rate at which the blood cools is distinctly slower than it would be were no caloric evolved; and that he observed the thermometer rise one degree at the commencement of coagulation. On the other hand, Dr. John Davy,[9] Mr. Thackrah, and Schröder van der Kolk,[10] accord with Mr. Hunter in the belief, that the increase of temperature from this cause is very slight or null, whilst M. Raspail asserts that the temperature falls.[11] *Again* we have to deplore the discordance amongst observers; and it will perhaps have struck the reader more than once, that such discordance applies as much to topics of direct

[1] Hist. Anatom. des Inflammations, ii. 426, Paris, 1826.
[2] Experiment. Inquiries, i. 19, Lond., 1774; or Sydenham Society's edit., Lond., 1846.
[3] Op. cit., p. 48.
[4] Inquiry into the Nature, &c., of the Blood, p. 38, Lond., 1819.
[5] Annales de Chimie, xii. 147.
[6] A Treatise on the Blood, &c., p. 27, Lond., 1794.
[7] Annals of Philosophy, iv. 139.
[8] An Essay on the Blood, p. 68, Lond., 1824.
[9] Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 6, Phila., 1840.
[10] Müller's Physiology, Baly's translation, p. 98, Lond., 1838.
[11] Chimie Organique, p. 361.

observation as to those of a theoretical character. The discrepancy regarding anatomical and physical *facts* is even more glaring than that which prevails amongst physiologists in accounting for the corporeal phenomena; a circumstance, which tends to confirm the notion promulgated by one of the most distinguished teachers of his day (Dr. James Gregory), that "there are more false facts in medicine" (and the remark might be extended to the collateral or accessory sciences) "than false theories."

There are certain substances, again, which, when added to the blood, prevent or retard its coagulation. Mr. Hewson found, that sulphate of soda, chloride of sodium, and nitrate of potassa were amongst the most powerful salts in this respect. Muriate of ammonia and a solution of potassa have the same effect. On the contrary, coagulation is promoted by alum, and by the sulphates of zinc and copper.[1] How these salts act on the fibrin, so as to prevent its particles from coming together, it is not easy to explain. But these are not the only inscrutable circumstances that concern the coagulation of the blood. Many causes of sudden death have been considered to have this result:—lightning and electricity; a blow upon the stomach; injury of the brain; bites of venomous animals; certain narcotico-acrid vegetable poisons; excessive exercise, and violent mental emotions, when they suddenly destroy, &c. Many of these affirmations, doubtless, rest on insufficient proof. For example, Sir C. Scudamore asserts that lightning has not this effect. Blood, through which electric discharges were transmitted, coagulated as quickly as that which was not electrified; and in animals killed by the discharge of a powerful galvanic battery, that in the veins was always found in a solid state. M. Mandl has summed up the results of modern experiments on the subject as follows. *First.* The alkalies—potassa, soda, and ammonia—completely prevent coagulation: lime retards it. *Secondly.* The soluble alkaline salts—combinations of soda, potassa, ammonia, magnesia, baryta and lime, with carbonic, acetic, nitric, phosphoric, tartaric, citric, boracic, sulphuric and cyano-hydric acid—also the chlorides, in very small quantity—favour coagulation. On the other hand, these substances in concentrated solution retard, and even prevent it entirely. The most active salts are the carbonates; the least so, combinations of chlorine, and sulphates. 0·007 of carbonate of soda retards coagulation for several hours, whilst the sulphates do not act in the proportion of 14 per 1000. The action of a salt is more marked in proportion as it reddens more the blood; whilst combinations of chrome, chlorine and iodine do not redden it, and do not prevent its coagulation. When water is added to blood thus liquefied by a salt it coagulates again—the fibrin being precipitated. *Thirdly.* Metallic salts decompose the blood; some causing coagulation; others preventing it. *Fourthly.* Very dilute vegetable acids favour it; when a little more concentrated, they prevent it; and when highly concentrated, decompose it like the mineral acids. *Fifthly.* The action of vegetable substances has not been sufficiently studied: some affirm, for instance, that narcotics prevent coagulation; others that they favour it. The same doubt exists in

[1] Magendie, Lectures on the Blood, in Lond. Lancet, reprinted in Bell's Select Medical Library, Philad., 1839.

regard to the action of poisons; it is generally believed, however, that they—as well as lightning, a violent discharge of electricity, the instantaneous destruction of the nervous system, &c.—prevent coagulation. *Sixthly.* Very dilute solutions of gum Arabic, sugar, albumen, milk, &c., appear to act only in a mechanical manner by preventing the approximation of the coagulated particles.

We shall find, hereafter, that the action of some of these agents has been considered evidence that the blood may be *killed;* and, consequently, that it is possessed of life. All the phenomena, indeed, of coagulation, inexplicable in the present state of our knowledge, have been invoked to prove this position. The preservation of the fluid state, whilst circulating in the vessels—although agitation, when it is out of the body, does not prevent its coagulation—has been regarded of itself, sufficient evidence in favour of the doctrine. Dr. Bostock,[1] indeed, asserts, that perhaps the most obvious and consistent view of the subject is, that fibrin has a natural disposition to assume the solid form, when no circumstance prevents it from exercising this inherent tendency. As it is gradually added to the blood, particle by particle, whilst that fluid is in a state of agitation in the vessels, it has no opportunity, he conceives, of concreting; but when suffered to remain at rest, either within or without the vessels, it is liable to exercise its natural tendency.

It is not our intention, at present, to enter into the subject of the vitality of the blood. The general question will be considered in a subsequent part of this work. We may merely observe, that, by the generality of physiologists, the blood is presumed, either to be endowed with a principle of vitality, or to receive from the organs, with which it comes in contact, a vital impression or influence, which, together with the constant motion, counteracts its tendency to coagulation.[2] Even M. Magendie,[3]—who is unusually and properly chary in having recourse to this method of explaining the *notum per ignotius,*—affirms, that instead of referring the coagulation of the blood to any physical influence, it should be considered as essentially a vital process; or, in other words, as affording a demonstrative proof, that the blood is endowed with life;—a position, which—as will be seen hereafter—is not tenable.[4]

M. Vauquelin discovered in the blood a considerable quantity of fatty matter, of a soft consistence, which he, at first, regarded as fat; but M. Chevreul,[5] after careful investigation, declared it to be identical with the matter of the brain and nerves, and to form the singular compound of an azoted or nitrogenized fat. Cholesterin has been detected in it by Gmelin,[6] and by Boudet.[7] MM. Prévost and Dumas, Ségalas, and others, have likewise demonstrated the existence of urea in the blood of animals, whose kidneys had been removed. Chemical analysis is, indeed, adding daily to our stock of information on this matter; and exhibiting to us, that many of the substances, which compose the tissues, exist in the blood in the very state in which we

1 Physiology, 3d edit., p. 271, Lond., 1836.
2 J. Müller, Handbuch, u. s. w., Baly's translation, p. 97, Lond., 1838.
3 Précis, &c., ii. 234.
4 See Book iv., chap. 5, on Life.
5 Bostock's Physiology, p. 294.
6 Chimie, iv. 1163.
7 Journ. de Pharmacie, Paris, 1833, and Annales de Chimie, lii. 337.

meet with them there. This is signally shown by the following table by Simon[1] of the constituents found in the blood of man, and certain mammalia.

	Water.		Iron (peroxide).
Protein compounds.	Fibrin. Albumen. Globulin.	Salts.	Albuminate of soda. Phosphates of lime, magnesia, and soda. Sulphate of potassa. Carbonates of lime, magnesia, and soda. Chlorides of sodium and potassium. Lactate of soda. Oleate and margarate of soda.
Colouring matters.	Hematin. Hemaphæin.		
Extractive matters.	Alcohol-extract. Spirit-extract. Water-extract.		
Fats.	Cholesterin. Serolin. Red and white solid fats containing phosphorus. Margaric acid. Oleic acid.	Gases.	Oxygen. Nitrogen. Carbonic acid.
			Sulphur.
			Phosphorus.

The analyses of M. Lecanu[2] are generally regarded as among the best. Blood obtained by him from two stout healthy men was found to be composed as follows:—

Water,	780·145	785·590
Fibrin,	2·100	3·565
Albumen,	65·090	69·415
Colouring matter (globules),	133·000	119·626
Fatty crystallizable matter,	2·430	4·300
Oily matter,	1·310	2·270
Extractive matter soluble in water and alcohol,	1·790	1·920
Albumen combined with soda,	1·265	2·010
Chloride of sodium, potassium, Carbonates, Phosphates, Sulphates of potassa and soda	8·370	7·304
Carbonates of lime and magnesia, Phosphates of lime, magnesia, and iron, Peroxide of iron,	2·100	1·414
Loss,	2·400	2·586
	100·000	100·000

On these analyses, Dr. Prout[3] has remarked, that gelatin is never found in the blood, nor any product of glandular secretion; and he adds, that a given weight of gelatin contains at least three or four per cent. less carbon than an equal weight of albumen. Hence, the production of gelatin from albumen, he conceives, must be a *reducing* process. We have seen, under the head of Respiration, what application he makes of these considerations.[4]

Researches on the ashes of human blood by Enderlin,[5] in the laboratory of Giessen, give the following as the quantitative analysis in 100 parts:—

[1] Animal Chemistry, Sydenham Society's edit., p. 166, Lond., 1845.

[2] Annales de Chimie et de Physique, xlviii. 308, and Journal de Pharmacie, Sept., 1831.

[3] Bridgewater Treatise, Amer. edit., p. 280, Philad., 1834.

[4] For the methods of analyzing the blood, see Simon, op. cit., p. 166.

[5] Annalen der Chemie und Pharmacie, Marz und April, 1844, cited by Mr. Paget, in Brit. and For. Med. Rev., Jan., 1845, p. 255.

Tribasic phosphate of soda,	22·1
Chloride of sodium	54·769
potassium,	4·416
Sulphate of soda,	2·461
Phosphate of lime,	3·636
magnesia,	0·769
Oxide of iron, with some phosphate of iron,	10·77

It has been inferred, from these analyses, that the albumen of the blood is not in the form of an albuminate of soda, or of a combination with carbonate or bicarbonate of soda, but in combination with the alkaline tribasic phosphate, and chloride of sodium,—the former salt possessing, in a high degree, the power of dissolving protein compounds and phosphates of lime, and probably being the solvent of those constituents in the blood. Dr. John Davy,[1] however, thinks, that even admitting the accuracy of Enderlin's results, the propriety of applying them to the condition of the alkali in liquid blood may be questioned. Carbonate of soda, he observes, is decomposed when heated with phosphate of lime; and when added in small quantity to blood is not to be detected in its ashes. This may account for its not having been found there. Were the opinion, referred to, correct, an acid added to blood or its serum, after the action of the air-pump, ought not on re-exhaustion to occasion a farther disengagement of air; but Dr. Davy finds that it does. This and other results induce him to give the preference to the conclusion, that blood contains sesquicarbonate of soda.

M. Dutrochet believed, that he had formed muscular fibres from albumen by the agency of galvanism; and supposed, that the red corpuscles of the blood formed each a pair of plates, the nucleus being negative, the envelope positive; but Müller[2] has shown, that all the appearances, which he attributed to different electric properties of the blood, are explicable by the precipitation of the albumen and fibrin in consequence of the decomposition of the salts of the serum and of the oxidation of the copper wire used in the experiments,—both the decomposition of the salts and the oxidation of the copper being the usual effects of galvanic action. With the galvanometer he was unable to discover any electric current in the blood; and he perceived no variation in the needle of the multiplicator, when he inserted one wire into an artery of a living animal, and the other into a vein.

Interesting experiments and observations on the blood were published several years ago by Dr. Benjamin G. Babington.[3] The principal experiment was the following. He drew blood in a full stream into a glass vessel filled to the brim, from the vein of a person labouring under acute rheumatism. On close inspection, a colourless fluid was immediately perceived around the edge of the surface, and after a rest of four or five minutes, a bluish appearance was observed forming an upper layer on the blood, which was owing to the subsidence of the red corpuscles to a certain distance below the surface, and the consequent existence of a clear liquor between the plane of the corpuscles and the eye. A spoon, previously moistened with water, was now immersed into the upper layer of liquid, by a gentle depression of

[1] Proceedings of the Royal Society of Edinburgh, vol. ii. No. 26, for 1845.
[2] Handbuch, u. s. w., Baly's translation, p. 133.
[3] Med.-Chirurg. Transact., vol. xvi., Part 2, Lond., 1831; and art. Blood (Morbid Conditions of the) in Cyclop. Anat. and Physiol., Lond., 1836.

one border. The liquid was thus collected quite free from red corpuscles, and was found to be an opalescent, and somewhat viscid solution, perfectly homogeneous in appearance. By repeating the immersion, it was collected in quantity, and transferred to another vessel. That which Dr. Babington employed was a bottle holding about 180 grains, of globular form, with a narrow neck and perforated glass stopper. The solution with which the globular bottle was filled, though quite homogeneous at the time it was thus collected, was found, after a time, to separate into two parts, viz., into a clot of fibrin, which had the precise form of the bottle into which it was received; and a clear serum, possessing all the usual characters of the fluid. From this experiment, Dr. Babington inferred, that buffed blood, to which we shall have to refer under another head, consists of only two constituents, red corpuscles, and a liquid to which he gives the name *liquor sanguinis*—*plasma* of Schultz—so called by him, because he esteems it to be the true nutritive and plastic portion of the blood, from which all the organs of the body are formed and nourished.

It has long been observed, that the blood of inflammation is longer in coagulating than the blood of health, and that the last portion of blood drawn from an animal coagulates quickest. The immediate cause of the buffy coat is thus explained by Dr. Babington. The blood, consisting of liquor sanguinis and insoluble red corpuscles, preserves its fluidity long enough to permit the corpuscles, which are of greater specific gravity, to subside through the liquor sanguinis. At length, the liquor sanguinis separates, by a general coagulation and contraction, into two parts; and this phenomenon takes place uniformly throughout the liquor. That part of it, through which the red corpuscles had time to fall, furnishes a pure fibrin or buffed crust, whilst the portion into which the red corpuscles had descended furnishes the coloured clot. This, in extreme cases, may be very loose at the bottom, from the great number of red corpuscles collected there, each of which has supplanted its bulk of fibrin, and consequently diminished its firmness in that part. There is, however, with this limitation, no more fibrin in one part of the blood than another. Researches by Mr. Gulliver[1] would seem to show, that the rate at which the red corpuscles sink in a fluid may give a very incorrect measure of its tenuity, since they subside much slower in serum, or in liquor sanguinis made thinner and lighter by weak saline solutions, than in the same animal fluids made thicker and heavier by gum. The blood, too, may have its coagulation retarded, whilst it is thinned and reduced in specific gravity; and yet no buffy coat appear. The greater aggregation of the corpuscles, observed by Mr. T. Wharton Jones,[2] and subsequently in his experiments, seemed to him to be connected with the accelerated rate of subsiding; as it was prevented or reversed by salts, which dispersed the corpuscles, and increased by viscid matters, which increased the aggregation. It is a well-known fact, that the shape of the vessel into which the blood is received influences the depth of the buff. The space, left by the gravitation of the red corpuscles, bears a proportion to the whole perpendicular depth of the

[1] Dublin Med. Press, Dec. 11, 1844.
[2] Edinburgh Med. and Surg. Journal, Oct. 1843, p. 309.

blood, so that in a shallow vessel scarcely any buff may appear, whilst the same blood in a deep vessel would have furnished a crust of considerable thickness; but Dr. Babington asserts, that even the quantity of the crassamentum is dependent, within certain limits, on the form of the vessel. If this be shallow, the crassamentum will be abundant; if approaching the cube or sphere in form, it will be scanty. The difference is owing to the greater or less distance of the coagulating particles of fibrin from a common centre, which causes a more or less powerful adhesion and contraction of those particles. This is a matter of practical moment, inasmuch as blood is conceived to be thick or thin, rich or poor, in reference to the quantity of crassamentum: and pathological views are entertained in consequence of conditions, which, after all, may depend not perhaps on the blood itself, but on the vessel into which it is received.

To remove an objection, that might be urged against a general conclusion deduced from the experiment cited,—that it was made upon blood in a diseased state,—Dr. Babington received healthy blood into a tall glass vessel half filled with oil, which enabled the red corpuscles to subside more quickly than would otherwise have been the case. This blood was found to have a layer of liquor sanguinis, which formed a buffy coat, whilst a portion of the same blood, received into a similar vessel, in which there was no oil, had no buff. Hence, it appeared, that healthy blood is similarly constituted as blood disposed to form a buffy coat, the only difference being, that the former coagulates more quickly than the latter. Dr. J. Davy,[1] however, has observed, that inflammatory blood, in some instances, does not coagulate more slowly than healthy blood, and as from the experiments of Professor Müller[2] it would appear that the presence of fibrin in the blood favours the subsidence of the red particles, Müller was led to infer, that the formation of the buffy coat may arise from the blood containing a larger quantity of fibrin, which the blood of inflammation is known to do. So that the principal causes, he thinks, of the subsidence of the red particles and the formation of the buffy coat in inflammatory blood, appear to be—the slow coagulation of the blood, and the increased quantity of fibrin. The most correct view, however, is, perhaps, that of M. Andral,[3] that the essential condition of the buffy coat is an increase in the quantity of fibrin in proportion to the red corpuscles. Hence, if there be an absolute increase of fibrin, the red corpuscles remaining the same, as in inflammation; or, if there be a diminution in the proportion of the red corpuscles, the fibrin remaining the same, as in chlorosis, the buffy coat may result; provided only there be—as there probably always is under such circumstances—a greater aggregation of the corpuscles.

An interesting fact connected with this subject has been noticed by Mr. T. Wharton Jones.[4] If a single drop of inflammatory blood be examined by the microscope, it will be seen that the red corpuscles have an unusual attraction for each other, which occasions them to coalesce in piles and masses, as in the marginal illustration, *b*, Fig. 119,

[1] Philosophical Transactions, for 1822. [2] Op. citat., p. 117.

[3] Hématologie Pathologique, p. 75, Paris, 1843, or Meigs's and Stillé's translation, Philad., 1844.

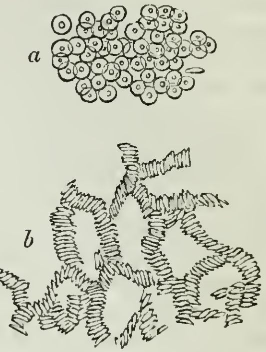
[4] Edinburgh Medical and Surgical Journal, Oct., 1843, p. 309.

leaving wide interspaces for the fibrin, lymph-corpuscles, and serum. It is probable, too, that there is an increased attraction between the particles of the fibrin, which will account for the firmer clot of the blood of inflammation.

The fact of a single drop of blood being sufficient to indicate the character of the whole mass may be important in cases where a doubt exists as to the propriety of bleeding to any extent.

It is proper to remark, that the researches of Mulder[1] have led him to infer, that the buffy coat does not consist of true fibrin, but is a compound of a binoxide of protein, which is insoluble in boiling water, and a tritoxide, which is soluble. These oxides Mulder comprehends under the name *oxyprotein*.

Fig. 119.



Aggregation of Corpuscles in Healthy and in Inflamed Blood.

a. Healthy blood. *b.* Inflamed blood.

It may, also, be remarked, that in all experiments on the horse, whenever the blood flows from an opened vein in a continuous stream, with a sufficiently strong jet, and is received into a vessel that is neither too shallow nor too wide, the upper part of the clot is instantly found occupied by a white mass, which perfectly resembles the buff of the blood of man. Such was the result of the observations of MM. Andral, Gavarret, and Delafond.[2]

It need scarcely be said, that venous blood, composed as it is in part of the products of heterogeneous absorption, must differ in its character in the different veins. In its passage through the capillary or intermediate circulation, the arterial blood is deprived of several of its elements, but this deprivation is different in different parts of the body. That, for example, which returns from the salivary glands, must vary from that which returns from the kidneys. In the blood of the abdominal venous system, the greatest variation is observed. Professor Schultz[3] has inquired into the chemical and physiological differences between that of the vena porta and of the arteries and other veins. He found, that it is not reddened by the neutral salts, or by exposure to the atmosphere, or to oxygen; that it does not generally coagulate; contains less fibrin; proportionably more cruor, and less albumen; and has twice as much fat in its solid parts as that of the arteries and other veins; the proportions being as follows:—

Blood of the vena porta, ...	1·66 per cent.
of the arteries, ...	0·92
of the other veins, ...	0·83

Simon,[4] in his researches, also found a much less proportion of fibrin and a larger of fat and of colouring matter. The fat he ascribes to the fluids produced during the act of digestion, which are conveyed into the portal vein.

[1] Annalen der Chemie, u. s. w., Bd. xlviii., Heidelb., 1843; cited by Mr. T. Wharton Jones, in Brit. and For. Med. Rev., July, 1844, p. 259.

[2] Essai d'Hématologie Pathologique, p. 27, Paris, 1843.

[3] Rust, Magazin für die gesammt. Heilkund., Bd. 44, H. i.; and Lond. Lancet, Aug. 10, 1839, p. 717.

[4] Animal Chemistry, Sydenham Society's edition, p. 208, Lond., 1845.

M. Jules Béclard[1] always found the cipher of red corpuscles in the blood of the splenic vein less than in that of the jugular; with a corresponding augmentation in the amount of solid matters in the serum, and a constant increase of fibrin. Otto Funke,[2] however, contests the accuracy of M. Béclard's analyses, and affirms, as the result of numerous careful observations, that there is always a diminution of the fibrin in the blood of the splenic vein; and that this is the only constant article of difference between the blood that enters and that which issues from the spleen; and Lehmann[3] remarks, that the investigations of Funke "afford, at all events, a proof, that the greatest caution is necessary in deducing conclusions from individual analyses, and investigations of individual fluids, without reference to the simultaneous constitution of the other animal juices. Many ingenious conclusions would no doubt have been deduced from analyses of the blood of the splenic vein, if the arterial blood had not been simultaneously compared with it." The mean of four observations of the blood of the splenic vein of a criminal, by Vierordt, is said to have given the ratio of colourless corpuscles to the coloured as 4·9 to 1. [?][4]

The following table by Mr. Gray,[5] who was assisted in his chemical researches by Dr. Noad, exhibits in a tabular form the average results of 111 analyses of the aortic, jugular, and splenic venous blood of the horse:—

	Aortic.	Jugular.	Splenic.
Clot,	159·50	141·00	95·12
Ash in ditto,	1·04	0·86	0·71
Serum,	840·50	859·00	904·88
Spec. gravity of ditto,	1032·5	1031·14	1032·24
Water,	789·14	793·42	829·81
Albumen,	42·00	54·40	63·00
Fibrin,	2·26	4·15	6·32
Fat in ditto,	·04	0·05	0·22
Globules,	157·20	136·80	88·58
Oily matters,		·35	·64
Crystalline fat,	·30	·49	·92
Alcohol extract,	2·42	1·61	3·27
Water extract,	6·64	8·73	7·24

Mr. Gray considers the chief chemical peculiarities of splenic venous blood to consist in a very considerable diminution of the blood corpuscles, an increase of the iron, albumen, and fibrin, and a deep reddish-brown colour of the serum.

The subject of the changes produced on the portal blood, more especially as regards the quantity of red corpuscles, will be referred to when considering the functions of the SPLEEN.

The character and quantity of the different constituents of the blood, as well as its coagulation, vary greatly in disease; and the investigation is one of the most important in the domain of pathology. It is one that has attracted the attention of modern pathologists, and especially of MM. Andral and Gavarret, and of Simon, and MM. Becquerel and Rodier, who have endeavoured to detect the changes that occur in dis-

[1] Archiv. Général. de Méd., Oct., 1848; and Traité Élémentaire de Physiologie Humaine, p. 411, Paris, 1855.

[2] Rudolph Wagner's Lehrbuch der speciellen Physiologie, S. 119, Leipzig, 1854.

[3] Physiological Chemistry, translated from the 2d edit., by Dr. Day; Amer. edit., by Dr. Rogers, i. 631, Philad., 1855.

[4] Schmidt's Jahrbüch., x. 789, in Brit. and For. Med.-Chir. Rev., April, 1855, p. 559.

[5] Cited by Dr. Day, in Brit. and For. Med.-Chir. Rev., July, 1855, p. 216.

ease in the amount of the organic elements of the fluid. These the author has referred to in their appropriate places in another work.[1] The usual proportions of each element, in 1000 parts of healthy blood, according to M. Lecanu, adopted by MM. Andral and Gavarret, are as follows:—

Fibrin,	3
Red corpuscles,	127
Solid matter of serum,	80
Water,	790

The average of analyses of the blood of nine healthy individuals—four females and five males, by Dr. Ch. Frick,[2] of Baltimore, corresponds nearly with the above.

According to Simon,[3] the proportions are somewhat different,—resulting, in a great measure, from a different method of analysis. The mean of his observations gave—

Water,	795·278
Solid residue,	204·022
Fibrin,	2·104
Fat,	2·346
Albumen,	76·600
Globulin,	103·022
Hematin,	6·209
Extractive matter and salts,	12·012[4]

The following table exhibits the mean composition of the blood, in eleven cases, as observed by MM. Becquerel and Rodier.[5]

Density of the defibrinated blood,	1060·2
" of the serum,	1028
Water,	779
Corpuscles,	141·1
Albumen,	69·4
Fibrin,	2·2
Extractive matters and free salts,	6·8
Fatty matters,	1·6
Serolin,	0·02
Fatty phosphuretted matter,	0·488
Cholesterin,	0·088
Soapy matter,	1·004

One thousand parts of calcined blood contained—

Chloride of sodium,	3·1
Soluble salts,	2·5
Phosphates,	0·334
Iron,	0·565

From these numbers they draw the following deductions. *First.* The limits within which the composition of healthy blood varies are restricted, and probably dependent on constitution, age, and diet. *Secondly.* The number for the corpuscles exceeds 127, which has been regarded as expressing the healthy mean. *Thirdly.* The number for the fibrin, 2·2, is below that usually admitted as the mean of that element, 3.

[1] Practice of Medicine, 3d edit., Philad., 1848.
[2] American Journal of the Medical Sciences, Jan., 1848, p. 27.
[3] Animal Chemistry, p. 245.
[4] It is proper to remark, with Simon, that the sum of the hematin and globulin, in his analysis, can never represent the absolute quantity of blood corpuscles. In his method the nuclei and capsules of the blood corpuscles are estimated as albumen; in that of Berzelius as fibrin; and in that of MM. Andral and Gavarret, as appertaining to the corpuscles.
[5] Gazette Médicale de Paris, Nos. 47, 48, 49, 50, and 51, for 1844.

The following tables have been constructed chiefly from the analyses of Denis, Lecanu, Simon, Nasse, Lehmann, Becquerel and Rodier, and Gavarret; and "are designed to combine, as far as possible, the advantage of accuracy in numbers with the convenience of presenting at one view a list of all the constituents of the blood."[1]

Average proportions of the chief constituents in 1000 parts:—

Water,	784
Red corpuscles,	131
Albumen of serum,	70
Saline matters,	6·03
Extractive, fatty and other matters,	6·77
Fibrin,	2·2
	1000·

Average proportion of all the constituents of the blood in 1000 parts:—

Water,		784
Albumen,		70
Fibrin,		2·2
Red corpuscles,		
globulin,		123·5
hematin,		7·5
Fatty matters:		
Cholesterin,	0·08	1·3
Cerebrin,	0·40	
Serolin,	0·02	
Oleic and margaric acids,		
Volatile and odorous fatty acid,		
Fat containing phosphorus,		
Inorganic salts:		
Chloride of sodium,		3·6
Chloride of potassium,		0·36
Tribasic phosphate of soda,		0·2
Carbonate of soda,		0·84
Sulphate of soda,		0·28
Phosphates of lime and magnesia,		0·25
Oxide and phosphate of iron,		0·5
Extractive matter, with salivary matter, urea, biliary colouring matter, gases and accidental substances,		5·47
		1000·

The mode in which the ratio of the various elements of the blood is estimated is detailed by MM. Andral and Gavarret, Simon, and Becquerel and Rodier, in the works referred to. A simpler method has, however, been given by M. Figuier,[2] founded on the fact made known by Berzelius, that after the addition of a solution of a neutral salt to defibrinated blood, the corpuscles do not pass through bibulous paper. On the addition of two parts of a solution of sulphate of soda, of specific gravity 1·130, to one of blood, M. Figuier found, that the whole of the corpuscles remained on the surface of the filter. The following is his procedure. The fibrin is removed in the usual way by whipping; and dried, and weighed. The weight of the corpuscles is then ascertained, and that of the albumen by coagulating the filtered solution by means of heat. The proportion of water is determined

[1] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 54, Philad., 1853.

[2] Annales de Chimie et de Physique, ii. 503, cited in Ranking's Abstract, i. 299, Amer. edit., New York, 1845.

by evaporating a small known weight of the blood. The advantage of this plan consists in the facility with which the most important constituents may be determined without any difficult manipulations.

The proportion of fibrin, according to MM. Andral and Gavarret, may vary perhaps within the limits of health, from 2½ to 3½ parts in a thousand. The quantity cannot, however, be accurately estimated, inasmuch as it is always mixed with colourless corpuscles; from which, as Messrs. Kirkes and Paget[1] have remarked, it cannot be separated by any mode of analysis yet invented. "In health, they may, perhaps, add too little to its weight to merit consideration; but in many diseases, especially in inflammatory and other blood diseases in which the fibrin is said to be increased, these corpuscles become so numerous that a large proportion of the supposed increase of the fibrin must be due to their being weighed with it. On this account all the statements respecting the increase of fibrin in certain diseases need revision."

The amount of red corpuscles appears to be subject to greater variation within the limits of health than that of the fibrin. The maximum is about 140, but this is connected with a plethoric condition: the minimum about 110. Strength of constitution contributes most to raise the corpuscles towards the maximum; whilst debility, congenital or acquired, diminishes them towards the minimum proportion. The solid matter of the serum likewise varies, but there is a certain point of diminution in health below which they do not pass.[2]

The analyses of MM. Becquerel and Rodier exhibit a marked difference in the proportion of the constituents of the blood of the two sexes. So great is this, that in order to attain correct conclusions in regard to morbid blood, it is indispensable to contrast it with the male or female blood in health. The average differences between the two are seen in the following table:—

	Male.	Female.
Density of defibrinated blood,	1060·0	1057·5
Density of serum,	1028·0	1027·4
Water,	779·0	791·1
Fibrin,	2·2	2·2
Sum of fatty matters,	1·60	1·62
Serolin,	0·02	0·02
Phosphorized fat,	0·488	0·464
Cholesterin,	0·088	0·090
Saponified fat,	1·004	1·046
Albumen,	69·4	70·5
Blood corpuscles,	141·1	127·2
Extractive matters and salts,	6·8	7·4
Chloride of sodium,	3·1	3·9
Other soluble salts,	2·5	2·9
Earthy phosphates,	0·334	0·354
Iron,	0·566	0·541

The main difference, consequently, between male and female blood is in the amount of water and blood corpuscles.[3]

[1] Manual of Physiology, 2d Amer. edit., p. 56, Philad., 1853.
[2] Andral, Hématologie Pathologique, p. 29, Paris, 1843.
[3] For the differences in blood, according to constitution, temperament, &c., see Simon, Animal Chemistry, Sydenham Society's edition, p. 236, Lond., 1845, or Amer. edit., Philad., 1846.

The following table by Henle,[1] gives the results of the analyses of different observers as regards the proportion of the organic constituents of human blood, and the corresponding specific gravities of blood and serum.

	S. G. of Blood.	S. G. of Serum.	Water.	Blood Corpuscles.	Residue of Serum.	Fibrin.	Observer.	Remarks.
1	1062	1031	772	128	97	2	Popp.	
2	1061		781	121	86	10	do.	Many colourless corpuscles.
3	1057		773	142	82	3		Few do.
4	1055	1028	799	130	75	3	Becquerel and Rodier.	
5	1055	1027	793	126	78	2	do.	
6	1053		771	146	78	4	Popp.	
7	1053		781	140	76	2	do.	
8	1051		802	117	76	5	do.	
9	1050		790	114	90	5	do.	Many do.
10	1049		803	120	71	5	do.	do.
11	1049		806	92	96	5	do.	do.
12	1048		791	128	76	2	do.	
13	1048		814	104	76	5	do.	Few do.
14	1048		806	124	66	4	do.	
15	1048		801	107	86	5	do.	Many do.
16	1048		811	95	86	8	do.	A moderate number of do.
17	1047		811	118	65	6	do.	
18	1047		794	121	81	4	do.	
19	1046		790	129	78	2	do.	
20	1046	1023	831	105	54	2	Becquerel and Rodier.	
21	1045	1024		78		3	do.	
22	1044		827	91	71	11	Popp.	
23	1044		801	100	86	12	do.	
24	1044		790	115	83	11	do.	A strong buffy coat.
25	1043		826	93	72	9	do.	Few colourless corpuscles.
26	1043		812	112	66	10	do.	A moderate buffy coat.
27	1042		812	105	77	6	do.	Few colourless corpuscles.
28	1042		821	91	84	4	do.	
29	1042		828	95	74	3	do.	Many colourless corpuscles.
30	1042	1022		92		2	Becquerel and Rodier.	
31	1041		816	77	94	13	Popp.	Strong buffy coat.
32	1041		817	99	76	8	do.	
33	1040		831	92	68	9	do.	
34	1040		827	92	76	4	do.	
35	1039		855	68	72	6	do.	Few colourless corpuscles.
36	1039		845	96	80	5	do.	
37		1030	792	126	81	2	do.	
38		1026	788	124	82	6	Heller.	
39		1025	773	146	77	4	do.	
40		1025	834	78	83	5	do.	
41		1024	820	87	85	8	do.	
42		1023	782	147	65	6	do.	
43		1011			58		Popp.	Serum rich in fat.

[1] Handbuch der Rationellen Pathologie, 2er Band. s. 18, Braunschweig, 1847.

There is considerable difference, however, amongst observers in regard to the ratio of the different organic constituents of healthy blood, and this is dependent upon the different modes of evaluation adopted by them. It is advisable, therefore, in observations made on diseased blood, to follow the method employed by some one of them; and that of MM. Andral and Gavarret is generally chosen.

To exhibit this difference the following table drawn up by Henle[1] may be introduced:—

1000 parts of healthy venous blood contain	Corpuscles.	Water.	Fibrin.	Albumen.	Extractive matters.	Salts.
According to Le Canu,	127	790	3	72		8
" Becquerel and Rodier,						
of men,	141·1	779	2·2	69·4	8·4	
of women,	127·2	791·1	2·2	70·5	9	
" Popp,	120	790	2·5		88	
" Zimmerman,	127		3		80	
" Simon,						
of men,	112·2	791·9	2·0	75·6	16·6	
of women,	106·0	798·6	2·2	77·6	12·6	
" Christison,						
of men,	153·5	756·2	5·2		85·3	
of women,	120·7	795·2	2·5		81·6	
" Hittorf,						
of women,	126·4	793·0	1·4	67·4	11·5	

An analysis of healthy human blood by Scherer[2] gives the following proportion of the various constituents:—

	I.	II.	III.
Water, ...	783·18	769·64	775·7
Fixed parts, ...	216·82	230·36	224·3
Fibrin, ...	2·30	2·03	2·63
Albumen, ...	63·34	68·45	70·08
Blood corpuscles, ...	139·92	146·22	138·71
Extractive matters, ...	5·16	5·34	3·84
Soluble salts, ...	8·85	8·86	9·04
Fat, ...	1·70		

It may be added, that a peculiar entozoon,—*polystoma venarum*, *hexathyridium venarum*,—has been found in human venous blood, especially in that of persons affected with hæmoptysis; Treutler found one in the tibial vein of a young man, who had lacerated it whilst bathing. Vogel, however, suggests, that it may have been a planaria, which had entered the vein from without;[3] and Valentin several times observed minute entozoa—*anguillulæ intestinales*—in the circulating blood of frogs. MM. Gruby and Delafond[4] communicated to the *Académie Royale des Sciences* of Paris, the discovery of filariæ in the circulating fluid of a living dog.

[1] Op. cit., s. 73.

[2] Canstatt's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, s. 65, Erlangen, 1849.

[3] The Pathological Anatomy of the Human Body, English translation by Day, p. 467, Lond., 1847.

[4] Philad. Med. Examiner, Jan. 13, 1844, from Comptes Rendus.

3. PHYSIOLOGY OF THE CIRCULATION.

The blood, contained in the circulatory apparatus, is in constant motion. The venous blood, brought from every part of the body, is emptied into the right auricle; from the right auricle it passes into the corresponding ventricle; and the latter projects it into the pulmonary artery, by which it is conveyed to the lungs, passing through the capillary system into the pulmonary veins; these convey it to the left auricle; from the left auricle it enters the corresponding ventricle; and the left ventricle sends it into the aorta, along which it passes to the different organs and tissues of the body, through the general intermediate or capillary system, which communicates with the veins; these return it to the part whence it set out. This entire circuit includes both the lesser and the greater circulation.

It was not until the commencement of the seventeenth century, that any precise ideas were entertained regarding the general circulation. In antiquity, the most erroneous notions prevailed; the arteries being generally looked upon as tubes for the conveyance of some aerial fluid to, and from, the heart; whilst the veins conducted the blood, whither or for what precise purpose was not understood. The names, given to the principal arterial vessel—*aorta*—and to the *arteries*, sufficiently show the functions originally ascribed to them,—both being derived from the Greek, αηρ, "air," and τηρειν, "to keep;" and this is farther confirmed by the fact, that the trachea or windpipe was originally termed an artery,—the αρτηρια τραχεια of the Greek,—*aspera arteria* of the Latin writers.[1] In the time of Galen, however, the arteries were known to contain blood; and he seems to have had some notions of a circulation. He remarks, that the chyle, the product of digestion, is collected by the meseraic veins and carried to the liver, where it is converted into blood; the supra-hepatic veins then carry it to the pulmonary heart; whence a part proceeds to the lungs, and the remainder to the rest of the body, passing through the median septum of the auricles and ventricles. This limited knowledge of the circulation continued through the whole of the middle ages,—the functions of the veins being universally misapprehended; and the general notion being, that they also convey blood from the heart to the organs; from the centre to the circumference.

It was not until after the middle of the sixteenth century, that the lesser circulation or that through the lungs was comprehended by Michael Servetus,—who fell a victim to the persecution and intolerance of Calvin,—and by Andrew Cæsalpinus and Realdus Columbus. It has been imagined, that they possessed some notion of the greater circulation. Howsoever this may have been, all nations unite in awarding to Harvey the merit, if not of entire originality of at least having first clearly established it.[2] The honour of the discovery is, therefore, his; and by it his name has been rendered immortal,—for its importance to the knowledge of the physiology and pathology of the

[1] "Spiritus ex pulmone in cor recipitur et per arterias distribuitur, sanguis per venas." Cicero, De Naturâ Deor., Lib. ii.

[2] "Lorsque Harvey parut, tout, relativement à la circulation, avait été indiqué ou soupçonné; rien n'était établi." Flourens, Histoire de la Découverte de la Circulation du Sang, p. 28, Paris, 1854.

animal fabric is overwhelming. How vague and inaccurate must have been the notions of the early pathologists regarding the doctrine of acute diseases, in which the circulation is always largely affected,—diseases, which, according to the estimate of some writers, constitute two-thirds of the morbid states to which mankind are liable!

It was in the year 1619, that Harvey attained a full knowledge of the circulation; but his discovery was not promulgated until the year 1628, in a tract, to which the merit of clearness, perspicuity, and demonstration has been awarded by all.[1] Yet so strong is the force of prejudice, and so difficult is it to discard preconceived notions, that according to Hume,[2] it was remarked, that no physician in Europe, who had reached forty years of age, ever, to the end of his existence, adopted Harvey's doctrine of the circulation; and Harvey's practice in London diminished extremely for a time from the reproach drawn upon him by that great and signal discovery.

Of the truth of the course of the blood, as discovered by Harvey, we have numerous and incontestable evidences, which it is almost a work of supererogation to adduce. Of these the following are some of the most striking. *First.* If we open the chest of a living animal, we find the heart alternately dilating and contracting so as manifestly to receive and expel the blood in reciprocal succession. *Secondly.* The valves of the heart, and of the great arteries that arise from the ventricles, are so arranged as to allow the blood to flow in one direction, and not in another; and the same may be said of the veins, which are directed towards the heart. The tricuspid valve permits the blood to flow only from the right auricle into the corresponding ventricle; the sigmoid valves admit it to enter the pulmonary artery, but not to return; and, as there is, in the adult, no immediate communication between the right and left sides of the heart, the blood must pass along the pulmonary artery and the pulmonary veins to the left auricle. The mitral valve, again, is so situate, that the blood can only pass in one direction from auricle to ventricle; and, at the mouth of the aorta, the same valvular arrangement exists as in the pulmonary artery, which permits the blood to proceed along the artery, but prevents its reflux. *Thirdly.* If an artery and vein be wounded, the blood will be observed to flow from the part of the vessel nearest the heart in the case of the artery; from the other extremity in that of a vein. The ordinary operation of bloodletting at the flexure of the arm affords an elucidation of this. The bandage is applied above the elbow, for the purpose of compressing the superficial veins, but not so tightly as to compress the deep-seated artery also. The blood passes along the artery to the extremity of the fingers, and returns by the veins; but its progress back to the heart by the subcutaneous veins being prevented by the ligature, they become turgid; and, if a puncture be made, it flows freely. If, however, the ligature be applied so forcibly as to compress the main artery, the blood no longer flows to the extremity of the fingers; there is none, consequently, to be returned by the veins; they do not rise properly; and if a puncture be made no blood flows. This is not an

[1] Exercitat. Anatom. de Motu Cordis et Sanguinis, Francof., 1628, Glasguæ, 1751.
[2] History of England, vol. vii. chap. lxii. p. 347, London, 1782.

unfrequent cause of the failure of an inexperienced phlebotomist. If the bandage, under such circumstances, be slackened, the blood resumes its course along the artery, and a copious stream issues from the orifice, which did not previously transmit a drop. This operation, then, exhibits the fact of the flow of blood along the arteries from the heart, and of its return by the veins. From what has been said, too, it will be obvious, that if a ligature be applied to both vessels, the artery will become turgid above the ligature, the vein below it. *Fourthly.* The microscopical experiments of Leeuenhoek, Malpighi, Spallanzani, and others have exhibited to the eye the passage of the blood in successive waves by the arteries towards the veins, and its return by the latter. *Lastly.* The fact is farther demonstrated by the effect of transfusion of blood, and of the injection of substances into the vessels; both of which operations will be alluded to in another place.

In tracing the physiological action of the different parts of the circulatory apparatus, we shall follow the order observed in the anatomical sketch; and describe, in succession, the circulation in the heart, arteries, capillary vessels, and veins; on all which points there has been interesting diversity of opinion, and much room for ingenious speculation, and farther improvement.

a. *Circulation in the Heart.*

It has been already observed, that when the heart of a living animal is exposed, it is remarked to undergo alternate contraction and dilatation. The mode, in which the circulation through the organ is accomplished is generally considered to be as follows.—The blood is received into the two auricles at the same time, and is transmitted into the two great arteries synchronously. In order that the heart shall receive blood, it is necessary that the auricle should be dilated. This movement is partly effected by virtue of the elasticity which it possesses in its structure. Let us suppose it to be once filled; the stimulus of the blood excites it to contraction, and the blood is sent into the corresponding ventricle. As soon, however, as it has emptied itself, the stimulus is withdrawn; and, by virtue of its elasticity the muscular structure returns to the state in which it was prior to its contraction. An approach to a vacuum is thus formed in the cavity, and the blood from the veins is solicited towards it, until it is again filled, and its contraction renewed. When the right auricle contracts there are four channels by which the blood might be presumed to pass from it,—the two terminations of the venæ cavæ; the coronary vein, and the auriculo-ventricular opening. The constant flow of blood from every part of the body prevents it from readily returning by the venæ cavæ, whilst the small quantity, which, under other circumstances, might have entered the coronary vein, is prevented by its valve. To the flow of the blood through the aperture into the ventricle, which is in a state of dilatation, there is no obstacle, and accordingly it takes this course, raising the tricuspid valves.

It may be remarked, that physiologists are not entirely of accord regarding the reflux of blood into the venæ cavæ. Some think, that this always occurs to a slight extent; others, never in the healthy state. Its existence is unequivocal, where an obstacle occurs to the due discharge of the blood into the ventricle. For example, if there is any impediment to the flow of blood along the pulmonary artery, either owing to mechanical obstruction or to diminished force of the ventricle, the reflux is manifested by a kind of pulsation in the veins, which Haller has called *venous pulse.*

The blood having attained the right ventricle by the effort exerted by the contraction of the auricle, and by the aspiration exerted by the dilatation of the cavity through the agency of its elastic structure, the ventricle contracts. Into it there are but two apertures, the auriculo-ventricular, and the mouth of the pulmonary artery. By the former, much of the blood cannot escape, owing to the tricuspid valve, which acts like the sail of a ship,[1]—the blood distending it as the wind does a sail, and the chordæ tendineæ retaining it in position, so that the greater part of the blood is precluded from reflowing into the auricle. This auriculo-ventricular valve is not, however, as perfect as that of the left heart. The observations of Mr. T. W. King[2] show, that whilst the structure of the mitral valve is adapted to close completely all communication between the left auricle and left ventricle during the contraction of the latter, that of the tricuspid valve is designedly calculated to permit, when closed, the flow of a certain quantity of blood into the auricle. The comparatively imperfect valvular function of the tricuspid was shown by various experiments on recent hearts, in which it was found, that fluids, injected through the aorta into the left ventricle, were perfectly retained in that cavity by the closing of the mitral valve; but when the right ventricle was similarly injected through the pulmonary artery, the tricuspid valves generally allowed the escape of the fluid in streams more or less copious, in consequence of the incomplete apposition of their margins. This peculiarity of structure in the tricuspid Mr. King regards as an express provision against the mischiefs, that might result from an excessive afflux of blood to the lungs,—thus acting as a safety valve, and being more especially advantageous in incipient morbid enlargements of the right ventricle. The only other way the blood can escape from the right ventricle is by the pulmonary artery, the sigmoid valves of which it raises. These had been closed like flood-gates, during the dilatation of the ventricle; but they are readily pushed outwards by the columns transmitted from the ventricle.

Such is the circulation through one heart,—the *pulmonic.* The same explanation is applicable to the other,—the *systemic;* and hence it is, that the structure, as well as the functions of the heart, is so much better comprehended, by conceiving it to be constituted of two essentially similar organs.

The above description is that which is usually given of the circulation through the heart. There is great reason, however, for the belief, that too much importance has been assigned to the distinct contraction of the auricles. If we examine their anatomical arrangement we discover, that there are no valves at the mouths of the great veins which open into them, and that although in the proper auricle or dog's ear

[1] Sir C. Bell, Animal Mechanics—Library of Useful Knowledge, p. 36.
[2] Guy's Hospital Reports, No. iv. for April, 1837.

portion muscular fibres and columns exist,—somewhat analogous to those of the columnæ carneæ of the ventricles, and probably destined for similar uses,—the parietes of the main portions of the auricles,—those that constitute the venous sinuses are but little adapted for energetic contraction. In experiments on living animals observation shows, that the rhythmic acts of dilatation and contraction are more signally exhibited by the ventricle, and, moreover, in some monsters the auricles are wanting, and in birds very small. M. d'Espine considers the auricles, in receiving or transmitting blood, to have only a vermicular motion, not one of contraction; and in a case of monstrosity, described by Dr. T. Robinson,[1] of Petersburg, Virginia, no distinct systole and diastole of the auricles could be detected. Besides, if we admit both an active power of dilatation and contraction in the ventricles, any similar action of the auricles would seem to be superfluous. In the state of active dilatation of the ventricles, the blood is drawn into their cavities; and as soon as they enter into contraction, the auriculo-ventricular valves prevent the farther entrance into them of blood arriving in the auricles by the large veins; and give occasion to the distension of the auricles; in this way, the dilatation of the auricles, synchronous with the contraction of the ventricles, is accounted for. As soon as the ventricle has emptied itself of its blood, it dilates actively; the blood then passes suddenly from the auricle into its cavity through the auriculo-ventricular opening.

From careful experiments instituted by Drs. Pennock and Moore,[2] they drew the following conclusions, which have been confirmed by the observations of others, and merit universal assent. The ventricles contract and the auricles dilate at the same time, occupying about one-half of the whole time required for contraction, diastole, and repose. Immediately at the termination of the systole of the ventricle, its diastole occurs, occupying about one-fourth of the whole time, synchronously with which the auricle diminishes, by emptying a portion of its blood into the ventricle, but without muscular contraction. The remaining fourth is devoted to the repose of the ventricles, near the termination of which the auricle contracts actively, with a short, quick motion, thus distending the ventricles with an additional quantity of blood: this motion is propagated immediately to the ventricles, and their systole follows so rapidly as to make the contraction of auricle and ventricle almost continuous. From the termination of their diastole to the commencement of the systole, the ventricles are in a state of perfect repose; their cavities remaining full but not distended; whilst those of the auricles are partially so, during the whole time. It appears probable, that the great use of the auricles—in which we include the sinuses—is to act as true gulfs for the reception of the blood proceeding from every part of the body; and that little effect is produced on the circulation by their varying condition.[3]

[1] American Journal of the Medical Sciences, No. xxii. for February, 1833.

[2] Medical Examiner, Nov. 2, 1839, and American Medical Intelligencer, Dec. 16, 1839, p. 277.

[3] See, on this subject, Elliotson's Human Physiology, p. 174, Lond., 1840, and Hiffelsheim, Comptes Rendus et Mémoires de la Société de Biologie, Année 1854, p. 273.

The state of the heart in which the ventricles are dilated is termed *Diastole;* that, in which they are contracted, *Systole.*

Since the valuable improvement, introduced by Laënnec in the discrimination of diseases of the chest by audible evidences, it has been discovered, that the heart is not in a state of incessant activity, but has, like other muscles, its intervals of repose. If we apply the ear or the stethoscope to the præcordial region, we hear, first, a dull, lengthened sound, which, according to Laënnec,[1] is synchronous with the arterial pulse, and is produced by the contraction of the ventricles. This is instantly succeeded by a sharp, quick sound, like that of the valve of a bellows, or the lapping of a dog. To convey a notion of these sounds, Dr C. J. B. Williams employs the word *lubb-dup* or *lubb-tub;*—the first word of the compound expressing the protracted first sound, and the latter the short second sound. The latter sound corresponds to the interval between two pulsations, and, according to Laënnec, is owing to the contraction of the auricles. The space of time, that elapses between this and the sound of the contraction of the ventricles, is the period of repose. The relative duration of these periods is as follows:—one-half, or somewhat less, for the contraction of the ventricles; a quarter, or somewhat more, for the contraction of the auricles; and the remaining quarter for the period of total cessation from labour. So that in the twenty four hours the ventricles work twelve hours, and rest twelve; and the auricles work six, and rest eighteen.

The following table by Messrs. Kirkes and Paget[2] exhibits the different actions of the heart, and their coincidence with the sounds and impulse of the organ. It presumes, that the period from the commencement of one pulsation to that of another—or that occupied by a complete set of the heart's actions—is divided into eight parts; and if the case of a person, whose pulse beats sixty times in a minute, be assumed, each of these parts will represent the eighth part of a second.

	EIGHTHS OF A SECOND.	
Last part of the pause,	1.	Auricles contracting: Ventricles distended.
First sound and impulse,	4.	Ventricles contracting: Auricles dilating.
Second sound,	2.	Ventricles dilating: Auricles dilating.
Pause,	1.	Ventricles dilating: Auricles distended.

Or it may be better exhibited in the following table. A series of the heart's actions (*rhythm*);—

Time = 4.

First or inferior sound. Time = 2.	Second or superior sound. Time = 1.	Interval or pause. Time = 1.
Ventricular contraction and auricular dilatation. Impulse.	First stage of ventricular dilatation.	Short repose, followed by contraction of auricles. Second stage of ventricular dilatation.

The view of Laënnec in regard to the second sound is manifestly erroneous. Ocular observation on living animals, as Dr. Alison[3] has

[1] A Treatise on the Diseases of the Chest, translated by Dr. Forbes, 4th edit., Lond., 1834.
[2] Manual of Physiology, 2d Amer. edit., p. 75, Lond., 1853.
[3] Outlines of Physiology, Lond., 1831.

remarked, shows that the emptying of the auricle precedes that of the ventricle, and that the interval of rest is between the contraction of the ventricle and the next emptying of the auricle: between the contraction of the auricle and that of the ventricle, there is no appreciable interval. Puchelt[1] thinks it most probable, that the first sound is caused by the impulse of the blood against the walls of the ventricle during the contraction of the auricles, and the second by the impulse of the blood against the commencement of the arteries during the contraction of the ventricles. In regard to the first sound, M. Beau[2]—and M. Valleix[3] accords with him—agrees pretty nearly with Puchelt. He ascribes it to the wave of blood striking against the parietes of the ventricles during the ventricular diastole. The second sound he ascribes, however, to the shock of the column of blood arriving by the veins against the parietes of the auricles. M. d'Espine thinks, that the first sound is produced by the contraction of the ventricles, and that the second is owing to their dilatation.[4]

Our knowledge of the causes of the sounds of the heart is, indeed, sufficiently imprecise; as is farther proved by the circumstance, that M. Magendie ascribed the first sound to the shock or impulsion of the apex of the heart during its diastole, and the second to the impulsion of the base of the heart during its systole; but the results of more recent experiments[5] led him to infer, that the first sound is owing to the contraction of the ventricles, and the impulse of the apex of the heart against the ribs; and the second to a similar impulse of the anterior part of the heart, produced by their dilatation. Dr. Billing[6] and M. Rouanet[7] ascribe the first or dull sound to the shock or impulse of the tricuspid and mitral valves against the auriculo-ventricular orifices; and the second or clear sound to the succussion of the blood in the distended aorta and pulmonary artery backwards against the semilunar valves, during the dilatation of the ventricles; and a similar opinion is entertained by Dr. Hope and by Messrs. Mayo[8] and Bouillaud.[9] In evidence that the first sound is due to the tension of the auriculo-ventricular valves, M. Valentin[10] states, that if a portion of a horse's intestine tied at one end be moderately filled with water, without any admixture of air, and have a syringe containing water adapted to the other end, the first sound of the heart will be exactly represented by forcing more water in. It may be distinctly heard with the stethoscope applied near the tied extremity of the intestine, at the instant the water from the syringe renders it tense. Mr. Carlisle[11] and Dr. Williams[12]

[1] System der Medicin., th. i. Auflage 2te, s. 149, Heidelb., 1835.

[2] Archiv. Général. de Méd., Déc., 1835, Janvier, 1839, Juillet, 1841.

[3] Guide du Médecin Praticien, tom. iii. p. 34, Paris, 1843.

[4] Revue Médicale, Oct., 1831.

[5] Annales des Sciences Naturelles, 1834.

[6] Lancet, May 19, 1832. See, also, First Principles of Medicine, 5th Eng. edit., p. xx., Lond., 1849, or 2d Amer. edit., Philad., 1851; and Practical Observations on Diseases of the Lungs and Heart, p. 11, Lond., 1852.

[7] Ibid., No. xcvii.; and Journal Hebdomadaire, Sept., 1832.

[8] Outlines of Human Pathology, p. 465, Lond., 1836.

[9] Journal Hebdomad., No. ix., 1834.

[10] Lehrbuch der Physiologie des Menschen, i. 427, Braunschweig, 1844.

[11] Report of the Third Meeting of the British Association for the Advancement of Science; and Amer. Journal of the Med. Sciences, p. 477, for Feb., 1835.

[12] A Rational Exposition of the Physical Signs of Diseases of the Lungs and Pleura, Amer. edit., Philad., 1830.

refer the first sound, with Laënnec, to the systole of the ventricles, and the second to the obstacle presented by the semilunar valves to the return of the blood from the arteries into the heart,—and Messrs. Corrigan,[1] Pigéaux,[2] Stokes,[3] and Mackintosh,[4] think the first sound is owing to the systole of the venous sinuses, and the second to the systole of the ventricles—an opinion, which Burdach[5] thinks is best founded, but which, as we have seen, is manifestly erroneous.

In a case of ectopia cordis, described by M. Cruveilhier,[6] a distinct vibratory thrill was perceived, by applying the finger to the origin of the pulmonary artery, which corresponded with the ventricular systole; but no such thrill could be felt when the finger was applied to any part of the base of the ventricles. He inferred, therefore, that the first sound cannot be dependent upon the action of the auriculo-ventricular valves. The greatest intensity of the first sound was, indeed, in the same situation as the greatest intensity of the second—that is, at the origin of the large arteries. Dr. Carpenter[7] thinks the results of these observations of Cruveilhier clearly establish, that the principal cause of the first sound exists at the entrances to the arterial trunks; and it does not seem to him, that any other reason can be assigned for it than the prolonged rush of blood through their orifices, and the throwing back of the semilunar valves, which, in suddenly flapping down again, produce the second sound. M. Cruveilhier states it, in his opinion, to be a uniform occurrence, that disease of the semilunar valves modifies both sounds;—a fact, which the author has long noticed. Without expressing an opinion as to the validity of M. Cruveilhier's conclusion respecting the two sounds of the heart, Dr. Forbes evidently regards it with favour, under the view long maintained by him, that although characteristically different, the two sounds have so great a similarity, and are so allied in time and place, that he could not readily bring his mind to believe, that they do not both depend upon one and the same cause slightly modified; or at least on the different play of the same parts.[8]

Drs. Pennock and Moore,[9] who agree in the main with Dr. Hope, found the first sound, the impulse, and the systole of the ventricles to be synchronous; and the second sound to be synchronous with the diastole of the ventricles. The first sound, they suggest, may be a combination of that caused by the contraction of the ventricles, the flapping of the auriculo-ventricular valves, the rush of blood from the ventricles, and the sound of muscular contraction. In four of their experiments, when the heart was removed from the body, the ventricles cut open and emptied of their contents, and the auriculo-ventricular valves elevated, a sound resembling the first was still heard, which

[1] Dublin Med. Trans., vol. i., New Series.
[2] Bulletin des Sciences Médicales, par Férussac, xxv. 272.
[3] Edinb. Med. and Surg. Journal, vol. xxxiv.
[4] Principles of Pathology, &c., 2d Amer. edit., ii. 6, Philad., 1837.
[5] Die Physiologie als Erfahrungswissenschaft, iv. 219, Leipz., 1832.
[6] Gazette Méd. de Paris, 7 Août, 1841, p. 535; or Brit. and For. Med. Review, Oct. 1841, p. 535.
[7] Human Physiology, § 486, Lond., 1842, and 5th Amer. edit., p. 477, Philad., 1853.
[8] Translation of Laënnec, 4th edit.; and Brit. and For. Med. Review, loc. cit.
[9] Op. citat.

they attributed chiefly to muscular contraction. The second sound they referred exclusively to the closure of the semilunar valves by the refluent blood from the aorta and pulmonary artery. "This," they remark, "is proved by the greater intensity of this sound over the aorta than elsewhere, the blood having a strong tendency to return through the valvular opening; by the greater feebleness of the sound over the pulmonary artery, which is short, and soon distributes its blood through the lungs, thus producing but slight impulse upon the valves in the attempt to regurgitate; by the disappearance of the sound when the heart becomes congested and contracts feebly; and finally, on account of its entire extinction when the valve of the aorta was elevated."

The main results of the experiments of Drs. Pennock and Moore accord closely with what the author has entertained and taught on this subject; but the views of M. Cruveilhier are well worthy of attention. The whole matter is still open for further investigation. A case of thoracic ectopia has been published by M. Monod,[1] in which the maximum intensity of the first sound did not occur at the base of the ventricles, but at the middle of their fleshy walls; and M. Monod thinks, that it was caused by the shock of the walls of the ventricles against the internal fleshy columns at the moment of contraction. As to the second sound, he is of opinion, that it was owing to the return of the wave of blood against the semilunar valves.

The mechanism by which the valves of the heart are closed, and its sounds produced, has been subjected to fresh investigation by Baumgarten, and subsequently by Hamernjk,[2] and others. According to them, there is, during the systole of the auricles, very little regurgitation into the venous trunks, owing, in part, to an arrangement of circular muscular fibres surrounding their openings into the auricles, as well as to the other causes generally admitted. The auriculo-ventricular valves—they conceive—are closed by the counterpressure of the ventricular blood, such counterpressure being suddenly developed by the contraction of the auricles. The cavities of the auricles and ventricles, during the diastole of the heart, are distended by the continuous current from the veins; and at this period the valves are floating in the blood in the form of a funnel. The object of the auriculo-ventricular systole is to induce such a degree of tension in the contents of the ventricles, and of necessity in the blood surrounding the funnel-shaped arrangement of the valves, as to cause their rapid closure and prevent regurgitation. Such closure is not due to the contraction of the musculi papillares, but is much facilitated by the small specific gravity of the valves, which enables them to float on the surface of the blood. The mechanism, by which the valves of the arteries are closed, is similar to that of the auriculo-ventricular valves. Immediately on the contraction of the ventricles, the pressure of the blood, contained in the large arterial trunks, acting equally in all directions, produces

[1] Bullet. del. Académ. Royale de Méd., 7 Février, 1843; cited in Edinb. Med. and Surg. Journal, July, 1843.

[2] Edinburgh Monthly Journal for Jan., 1849, cited from Prager Vierteljahrschrift, 1847 and 1848; see also Schmidt's Jahrbücher, No. 1, S. 10, Jahrgang 1848, and No. 5, S. 151, Jahrgang 1849.

the closure of the semilunar valves,—their complete closure occurring synchronously with the end of the ventricular systole. When the diastole of the ventricle commences, the arterial retraction begins, and the refluent blood from the large arteries falls on the valves already closed, and causes the second sound; but there is no regurgitation, as there necessarily would be—M. Hamernjk maintains—were the valve shut out by the returning wave of blood. The first sound, according to this view, is occasioned by the vibration of the tense auriculo-ventricular valves, caused by the blood forced against them in the systole of the ventricles, and the vibration of the chordæ tendineæ. In like manner, the second sound is produced by the impulse of the blood on the semilunar valves already shut, and not by their closure, as usually supposed.

The following table, compiled in part by MM. Barth and Roger,[1]—to which additions have been made by M. Bérard[2] and the author—affords at a glance the discordant opinions entertained by observers in regard to this important topic of physiology,—an accurate knowledge of which is essential to the correct understanding of cardiac diseases.

	FIRST SOUND CAUSED BY	SECOND SOUND CAUSED BY
LAENNEC,[3]	Ventricular contraction.	Auricular contraction.
TURNER,[4]	Do.	Shock of the heart falling back upon the pericardium during the diastole.
CORRIGAN,[5]	Shock of the blood against the ventricular parietes during the diastole.	Reciprocal shock of the internal surface of the opposite parietes of the ventricles during the systole.
MARC D'ESPINE,[6]	Ventricular contraction.	Ventricular dilatation.
PIGEAUX,[7] 1830,	Shock of the blood against the ventricular parietes at the moment of the diastole.	Shock of the blood against the parietes of the aorta and pulmonary artery at the moment of the systole.
PIGEAUX,[8] 1839,	Friction of the blood against the parietes of the ventricles, the orifices and parietes of the great vessels, at the moment of the systole.	Friction of the blood against the parietes of the auricles, the auriculo-ventricular orifices, and the cavity of the ventricles, at the moment of the diastole.
HOPE,[9] 1831,	Molecular collision of the blood in the systole.	Molecular collision of the blood in the diastole.
HOPE,[10] 1839,	Sound of tension of the auriculo-ventricular valves, sound of muscular extension, rotatory sound in the systole.	Clacking of the semilunar valves in the diastole.
BILLING,[11] ROUANET,[12] AND BÉCLARD,[13]	Clacking of the auriculo-ventricular valves in the systole.	Do.

[1] Traité Pratique d'Auscultation, &c., 2de édit., p. 359, Paris, 1844.
[2] Cours de Physiologie, iii. 667, Paris, 1851.
[3] Auscultation Médiate, ii. 399, Paris, 1826.
[4] Edinburgh Medico-Chirurgical Transactions, iii. 205.
[5] Dublin Medical Transactions, New Series, i. 151, Dublin, 1830.
[6] Journ. Hebdomad. de Méd., iv. 115, Paris, 1831.
[7] Ibid., iii. 238, and v. 187, Paris, 1831.
[8] Traité des Maladies du Cœur, p. 49, Paris, 1839.
[9] A Treatise on Diseases of the Heart, 1st edit., Lond., 1831.
[10] Ibid., 3d edit., Lond., 1839; or 2d Amer. edit., Philad., 1846.
[11] Op. cit.
[12] Thèses de Paris, 1832, No. 252.
[13] Traité Élémentaire de Physiologie, p. 188, Paris, 1855.

	FIRST SOUND CAUSED BY	SECOND SOUND CAUSED BY
PIORRY,[1]	Friction of the molecules of the blood against each other, and against the parietes of the ventricles, the orifices, and the valves, during the systole of the left ventricle.	Passage of the blood into the right cavities. Into what parts? At what moment?
PIÉDAGNEL,[2]	Contraction of the left ventricle.	Contraction of the right ventricle.
CARLISLE,[3]	Irruption of the blood into the arteries during the systole.	Clacking of the semilunar valves in the diastole.
MAGENDIE,[4]	Shock of the apex of the heart against the thorax at the moment of the systole.	Shock of the anterior surface of the heart at the moment of the diastole.
BURDACH,[5]	Irruption of the blood into the ventricles containing air (?) at the moment of the contraction of the auricles.	Projection of the blood into the arteries containing air (?) at the moment of the systole.
BOUILLAUD,[6]	Sudden tension (*redressement*) and shock of the opposed surfaces of the auriculo-ventricular valves, and sudden depression of the semilunar valves during the systole.	Tension (*redressement*) of the semilunar valves, and shock of their opposed surfaces, and sudden depression of the auriculo-ventricular valves at the moment of the diastole.
GENDRIN,[7]	Vibrations resulting from the collision of the blood in the systole.	Percussion of the blood against the parietes of the ventricles at the moment of the diastole.
CRUVEILHIER,[8]	Sudden tension (*redressement*) of the semilunar valves by the systole.	Depression of these valves at the moment of the diastole.
SKODA,[9]	*First ventricular sound.* Shock of the blood against the auriculo-ventricular valves; impulsion of the apex of the heart against the thorax. *First arterial sound.* Shock of the blood against the parietes of the aorta, and of the pulmonary artery in the systole.	*Second ventricular sound.* Shock of the column of blood against the parietes of the ventricles in the diastole. *Second arterial sound.* Retrograde shock of the column of blood upon the semilunar valves.
BEAU,[10]	Shock of the wave of blood against the parietes of the ventricles in the systole of the auricles.	Shock of the column of blood, arriving by the veins against the parietes of the auricles.
C. J. B. WILLIAMS,[11]	Muscular contraction of the ventricles during the systole.	Return shock of the columns of blood against the semilunar valves during the diastole.
DUBLIN COMMITTEE,[12]	Friction of the blood against the parietes of the ventricles, and muscular contraction during the systole.	Tension of the semilunar valves, and return shock of the columns of blood during the diastole.

[1] Archives Générales de Médecine, 2de série, v. 245.
[2] L'Union Médicale, p. 588, Paris, 1849.
[3] Dublin Journal of Medical Science, iv. 84, Dublin, 1834.
[4] Mém. de l'Acad. des Sciences, xiv. 155, Paris, 1838.
[5] Die Physiologie als Erfahrungswissenschaft, iv. 219, Leipzig, 1832.
[6] Traité Clinique des Maladies du Cœur, i. 115.
[7] Leçons sur les Maladies du Cœur, i. 54. [8] Gaz. Médicale, p. 497, Paris, 1841.
[9] Medicinisch. Jahrbüch. des Oester. Staat., xxii. 227.
[10] Archiv. Gén. de Méd., 2de série, ix. 389.
[11] Edinb. Med. and Surg. Journ., xxxii. 297, and xxxiii. 333. See, also, his Lectures on the Physiology and Diseases of the Chest, Amer. edit., Philad., 1839; and A Practical Treatise on the Diseases of the Respiratory Organs, edited by Dr. Clymer, p. 73, Philad., 1845.
[12] Dublin Journal of Medical Science, viii. 154.

	FIRST SOUND CAUSED BY	SECOND SOUND CAUSED BY
LONDON COMMITTEE,[1]	Sudden muscular tension of the ventricles in the systole, and shock of the heart against the thorax.	Sudden occlusion of the semilunar valves by the arterial columns of blood.
PENNOCK AND MOORE,[2]	Muscular contraction of the ventricles and clacking of the auriculo-ventricular valves during the systole.	Occlusion of the semilunar valves by the return shock of the arterial columns of blood.
BARTH AND ROGER,[3]	Contraction of the ventricles: shock at the inferior surface of the semilunar valves, and at the base of the aortic and pulmonary columns of blood; clacking of the auriculo-ventricular valves; and impulse of the heart against the chest.	Tension of the semilunar valves; and return shock of the blood on their concave surface.
BAUMGARTEN AND HAMERNJK,[4]	The vibration of the tense auriculo-ventricular valves acted on by the blood sent against them during the systole of the ventricles, and the vibration of the chordæ tendineæ.	The impulse of the blood on the semilunar valves already shut, not by their closure.

It has been a question with physiologists, whether the cavities of the heart completely empty themselves at each contraction. Sénac,[5] and Thomas Bartholine,[6] from their experiments, were long ago led to answer the question negatively. On the other hand, Haller[7] entertained an opposite opinion,—suggested, he remarks, by his experiments; but, perhaps, notwithstanding all his candour, connected, in some manner, with his doctrine of irritability, which could not easily admit the presence of an irritant in a cavity that had ceased to contract. It has been remarked by M. Magendie,[8] that if we notice the heart of a living animal, whilst it is in a state of action, it is obvious, that the extent of the contractions cannot have the effect of completely emptying the ventricles; but it must, at the same time, be admitted, that such experiments are inconclusive, inasmuch as they exhibit to us the action of the organ under powerfully deranging influences, and such as could be readily conceived to modify materially the extent of the contractions. The same may be said of a case of monstrous fœtus observed by Dr. Thomas R. Mitchell.[9] After each contraction of the ventricle he was able to make blood pass into the aorta. If the heart of a frog be examined by cutting out the lower portion of the sternum, owing to the transparency of the parietes of the heart, it can be observed that the ventricle completely empties itself at each contraction; but Dr. Mitchell is decidedly of opinion, that the frog is not a fit subject from which to draw a conclusion, and agrees with Mr. Carlisle, that the cavities empty themselves more completely in the lower order of animals than in the higher. These observations, however, are in-

[1] Lond. Med. Gaz., xix. 360. [2] Am. Journ. of the Med. Sci., xxv. 415.
[3] Op. cit. [4] Op. cit.
[5] Traité de la Structure du Cœur, &c., 2de édit., Paris, 1774.
[6] Dissertat. de Corde, Hafn., 1648.
[7] Element. Physiol., lib. iv. sect. 4, § 7, Lausann., 1757. [8] Précis, &c., tom. ii.
[9] Dublin Journal of Medical Science, Nov., 1844, p. 275.

sufficient to prove, that whilst an animal is in a normal condition, the auricles and ventricles are not emptied of their contents by their contraction.

The objection urged against the opposite view, that there would always be stagnant blood in the cavities of the heart, is not valid. The experiments of Venturi[1] have shown, that even in an ordinary hydraulic apparatus, the motion of a stream passing through a vessel of water is communicated to the fluid at rest in the vessel, so that an incessant change is produced.

During the systole of the heart, the organ is suddenly carried forward; and although it appears to be rendered shorter, its point or apex is generally considered to strike the left side of the chest opposite the interval between the fifth and seventh true ribs; producing what is called the "beating or impulse of the heart." The cause of this phenomenon was, at one period, a topic of warm controversy. Borelli,[2] Winslow, and others, affirmed, that it was owing to the organ being elongated during contraction; but to this it was replied by Bassuel,[3] that if such elongation took place, the tricuspid and mitral valves, kept down by the columnæ carneæ, could not possibly close the openings between the corresponding auricles and ventricles. Experiments by Drs. Pennock and Moore[4] exhibited to them, that the expulsion of the blood from the ventricles was effected by an approximation of the sides of the heart, and not by a contraction of the apex towards the base; and that, during the systole, the heart performs a spiral movement, and becomes elongated. Sénac[5] ascribed the beating of the heart to three causes, and his views have been adopted by most physiologists:—1, to the dilatation of the auricles, which occurs during the contraction of the ventricles; 2, to the dilatation of the aorta and pulmonary artery by the introduction of blood sent into them by the ventricles; and 3, to the straightening of the arch of the aorta, owing to the blood being forced against it by the contraction of the left ventricle. Dr. William Hunter[6] considered the last cause quite sufficient to explain the phenomenon, and many physiologists have assented to his view.

Sir David Barry[7] instituted some experiments upon this subject. He opened the thorax of a living animal, and by passing his hand into the cavity, endeavoured to ascertain the actual condition of the heart and great vessels, as to distension and relative position. He performed seven experiments of this kind, from which he concluded, that the vena cava is considerably increased in size during inspiration, which he ascribes, as will be better understood hereafter, to the partial vacuum formed in the chest. He supposes that the force exerted by the venous blood on entering the heart, in consequence of the expansion of the chest and the great vessels behind the heart, pushes the organ forwards, and thus causes it to strike against the ribs. Dr. Corrigan thinks,

[1] Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798; and Sir C. Bell, Animal Mechanics, p. 35, Library of Useful Knowledge, Lond., 1829.

[2] De Motu Animalium, Lugd. Bat., 1710.

[3] Magendie, Précis, &c., ii. 395.

[4] Med. Examiner, Nov. 2, 1839.

[5] Traité de la Structure du Cœur, &c., Paris, 1749.

[6] John Hunter, Treatise on the Blood, p. 146, Lond., 1794.

[7] Exper. Researches on the Influence of Atmospheric Pressure upon the Circulation, Lond., 1826.

that the apex of the heart has nothing to do with the impulse. He is of opinion that the heart acts like any other muscle,—that as soon as the ventricles contract, it is shortened from below upwards, and by this shortening becomes thickened in the middle, in a similar manner to the thickening of the belly of the biceps muscle, which, when it contracts, gives rise to an evident impulse, plainly perceptible to the hand applied to it; and that in like manner the heart's impulse is owing to the body of the ventricles, and not to the apex, striking against the ribs. Dr. Corrigan's view is considered by Dr. T. R. Mitchell,[1] to be confirmed by the phenomena observed by him on a fœtus born with the left side of the thorax wanting; and in which the action of the heart could be closely observed. Drs. Pennock and Moore,[2] however, in their experiments, found that the impulse was synchronous with and caused by the contraction of the ventricles, and when felt externally, arose from the striking of the apex against the thorax. In the celebrated case, too, of the son of Viscount Montgomery, detailed by Harvey,[3] where there was an opportunity of inspecting the movements of the heart, it was particularly observed, "that in the diastole the organ was retracted and withdrawn; whilst, in the systole, it emerged and protruded; and the systole of the heart took place at the moment the diastole or pulse in the wrist was perceived: to conclude, the heart struck the walls of the chest, and became prominent at the time it bounded upwards and underwent contraction on itself." To show, however, that this apparently simple matter cannot be considered settled, Professor Müller[4] thinks that great uncertainty rests as to whether the impulse is produced during the contraction or the dilatation of the ventricles; yet it certainly cannot occur during the first stage of ventricular diastole. In proof, however, that the impulse of the heart is dependent on the contraction of the muscular fibres of the ventricles, the experiments of Valentin[5] may be cited. He cut off the apex of the heart in several cases, so that the resistance of the blood and the great vessels, and the supposed consequent recoil, were prevented; yet the tilting movement was observed as much as when the heart was entire. It has even been supposed that the impulse is produced by the blood sent into the ventricles by the contraction of the auricles, but it must be borne in mind, in the inquiry, that there is no appreciable interval between the contraction of the auricles, and that of the ventricles; and that, therefore, both may be concerned.[6]

The systole of the heart is admitted by all to be active. Some are disposed to think the diastole passive,—that is, the effect of relaxation of the fibres, or the cessation of contraction. Pechlin, Perrault, Hamberger, d'Espine, Alison, and numerous others, have supported an opposite view;—affirming that direct experiment on living animals shows, that positive effort is exerted at the time of the dilatation of the cavi-

[1] Dublin Journal of Med. Science, Nov., 1844, p. 271. [2] Op. citat.

[3] The works of William Harvey, M. D., &c., p. 384, Sydenham Society's edit., Lond. 1847.

[4] Handbuch, u. s. w., Baly's translation, p. 175, Lond., 1838.

[5] Lehrbuch der Physiologie des Menschen, i. 427.

[6] See, in favour of the view, that the impulse is attributable to the diastole of the ventricle, Hardy and Béhier, Pathologie Interne, i. 326, Paris, 1844; and Dr. A. Stillé, Amer. Journ. of the Medical Sciences, July, 1846, p. 174.

ties;—a view confirmed by the case of monstrosity related by Dr. Robinson.[1] His opinion is, that the force of the diastole was in that case equal to, if not greater than, that of the systole. In the case, too, observed by M. Cruveilhier, the diastole had the rapidity and energy of a very active movement, overcoming pressure made upon the heart, so that the hand, closed upon it when it was contracted, was opened with violence. It has been suggested, that if the course of all the fibres composing the muscular parietes of the organ were better known, this apparent anomaly might, perhaps, be as easily explained as in the ordinary case of antagonist muscles. It is probable, however, that the active force exerted in the dilatation of these cavities is that of elasticity; and when the contraction of the muscular fibres has ceased, this is aroused to action, and promptly restores the organ to its previously dilated condition. According to this view, the natural state would be that of dilatation. In treating of this subject, Dr. Carpenter[2] suggests whether there may not exist in muscle an active force of elongation, as well as an active force of contraction, arising from the mutual *repulsion* of particles whose mutual attraction is the occasioning of the shortening.[?]

The cause of the heart's action has been a deeply interesting question to the physiologist, and, in the obscurity of the subject, has given rise to many and warm controversies. From the first moment of fœtal existence, at which the organ becomes perceptible, till the cessation of vitality it continues to move. By many of the ancients this was supposed to be owing to an inherent *pulsific virtue*,[3] which enabled it to contract and dilate alternately,—a mode of expression, which, in the infancy of physical science, was frequently employed to cover ignorance, and has been properly and severely castigated by Molière:—

> "Mihi a docto doctore
> Domandatur causam et rationem quare
> Opium facit dormire.
> A quoi respondeo;
> *Quia est in eo*
> *Virtus dormitiva,*
> Cujus est natura
> Sensus assoupire."
>
> LE MALADE IMAGINAIRE, Intermède iii.

It was in ridicule of the same failing that Swift represented the action of a smokejack to be depending on a meat-roasting power.[4] Descartes[5] imagined that an explosion took place in the ventricles as sudden as that of gunpowder. With equal nescience, the phenomenon was ascribed by Van Helmont[6] to his imaginary archæus; and by Stahl,[7] and the rest of the animists, to the *anima*, soul or intelligent principle, which he supposed to preside over all the mental and corporeal phenomena. Stahl was one of the first that attempted any rational explanation of the heart's action. Its muscular tissue; the similarity of its

[1] Amer. Journal of the Medical Sciences, No. xxii., Feb., 1833.
[2] Principles of Human Physiology, Amer. edit., page 249, Philad., 1855.
[3] Haller, Elementa Physiologiæ, lib. iv. sect. v. § 1.
[4] Fletcher, Rudiments of Physiology, P. ii. *a*., p. 52, Edinb., 1836.
[5] Tract. de Homine, p. 167, Amst., 1677. [6] Ortus Medicin. &c., Amstel., 1648.
[7] Theoria vera Medica, Hal., 1737.

contractions to those of ordinary muscles, with the exception of their not being voluntary; the fact of its action being modified by the passions, &c., led him to liken its movements to those of muscles. He admitted, that, generally, we possess neither perception of, nor power over, its motions; but he affirmed, that habit alone had rendered them involuntary; in the same manner as certain muscular twitchings or *tics*, which are at first voluntary, may become irresistible by habit. A strong confirmation of this opinion was drawn from the celebrated case of the honourable Colonel Townshend, (called by M. Adelon[1] and other French writers, Captain Towson,) who was able, (not all his life, as Adelon asserts, but a short time before his death,) to suspend the movements of his heart at pleasure. This case is of so singular a character, in a physiological as well as pathological point of view, that we shall give it in the words of Dr. George Cheyne,[2] one of the physicians who attended him, and whose character for veracity is beyond suspicion.

"Colonel Townshend, a gentleman of excellent natural parts, and of great honour and integrity, had, for many years, been afflicted with constant vomitings, which had made his life painful and miserable. During the whole time of his illness he had observed the strictest regimen, living on the softest vegetables and lightest animal food; drinking asses' milk daily, even in the camp; and for common drink Bristol water, which, the summer before his death, he had drunk on the spot. But his illness increasing, and his strength decaying, he came from Bristol to Bath in a litter, in autumn, and lay at the Bell Inn. Dr. Baynard, who is since dead, and I were called to him, and attended twice a day for about the space of a week: but, his vomitings continuing still incessant, and obstinate against all remedies, we despaired of his recovery. While he was in this condition, he sent for us early one morning; we waited on him with Mr. Skrine, his apothecary (since dead also); we found his senses clear, and his mind calm; his nurse and several servants were about him. He had made his will and settled his affairs. He told us he had sent for us to give him some account of an odd sensation he had for some time observed and felt in himself, which was that, composing himself, he could *die* or *expire* when he pleased, and yet by an effort, or somehow, he could come to life again; which it seems he had sometimes tried before he had sent for us. We heard this with surprise; but as it was not to be accounted for from tried common principles, we could hardly believe the fact as he related it, much less give any account of it; unless he should please to make the experiment before us, which we were unwilling he should do, lest, in his weak condition, he might carry it too far. He continued to talk very distinctly and sensibly above a quarter of an hour, about this (to him) surprising sensation, and insisted so much on our seeing the trial made, that we were at last forced to comply. We all three felt his pulse first; it was distinct, though small and thready; and his heart had its usual beating. He composed himself on his back, and lay in a still posture some time. While I held his right hand, Dr. B. laid his hand on his heart, and

[1] Physiol. de l'Homme, edit. cit., iii. 302.
[2] The English Malady, or Treatise of Nervous Diseases, p. 307, Lond., 1734.

Mr. S. held a clean looking-glass to his mouth. I found his pulse sink gradually, till at last I could not feel any, by the most exact and nice touch. Dr. Baynard could not feel the least motion in his heart, nor Mr. Skrine the least soil of breath on the bright mirror he held to his mouth. Then each of us, by turn, examined his arm, heart and breath, but could not by the nicest scrutiny discover the least symptom of life in him. We reasoned a long time about this odd appearance as well as we could; and all of us judging it inexplicable and unaccountable; and finding he still continued in that condition, we began to conclude indeed that he had carried the experiment too far, and at last were satisfied that he was actually dead, and were just ready to leave him. This continued about half an hour, by nine o'clock in the morning, in autumn. As we were going away, we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning; he began to breathe gently, and speak softly; we were all astonished, to the last degree, at this unexpected change, and after some further conversation with him, and among ourselves, went away fully satisfied as to all the particulars of this fact, but confounded and puzzled, and not able to form any rational scheme, that might account for it. He afterwards called for his attorney, added a codicil to his will, settled legacies on his servants, received the sacrament, and calmly and composedly expired about five or six o'clock that evening."

Dr. Cleghorn, of Glasgow, knew an individual who could feign death, and had so completely the power of suspending, or at least of diminishing the action of the heart, that its pulsations were imperceptible; and the singular cases of the Fakeers, of India, which will be referred to hereafter, indicate—if they are to be credited at all—that somatic life may be scarcely or not at all distinguishable, whilst molecular life may persist; as is witnessed during the hibernation of animals.

It is manifest that these cases—unaccountable as they are, in many respects—can add no weight to the views of the Stahlians. They are as strange, as they are inexplicable. The opinion, with them, that the heart's action is a muscular function was accurate. The error lay in placing it amongst the voluntary functions. It belongs to the involuntary class, equally with many of the muscles concerned in deglutition, and those of the stomach and intestines; and how well is it for us, as Sir Charles Bell has remarked, that its action as well as that of other organs directly instrumental to the organic functions is placed out of our control! "A doubt—a moment's pause of irresolution—a forgetfulness of a single action at its appointed time—would otherwise have terminated our existence."

The doctrine of Haller[1] on the heart's action rested upon the *vis insita* or *irritability* to which he referred all muscular contractions, voluntary and involuntary. This property, as stated in another place, he conceived to be possessed by muscles as muscles, independently of all nervous influence. The heart, being a muscle, enjoyed it of necessity: and the irritant, which incessantly developed it, was the blood.

[1] Op. citat.

In evidence of this, he observes, that its contractions are always more forcible and rapid, when the blood is more abundant; and that they occur successively in the cavities of the heart as the blood reaches them. So wholly did Haller assign the heart's action to this irritability, that he denied the nerves any influence over it; resting his belief on the admitted facts,—that it will continue to beat after decapitation; after the division of the spinal marrow in the neck; and of the nerves distributed to the organ; and, even after it has been entirely removed from the body. How far the opinions of this great man are correct, respecting the power of contraction residing in the heart, as he conceived it to do in other muscles, we shall inquire presently. It is, doubtless, indirectly under the nervous influence. We see it affected in the various emotions; sometimes augmenting violently, at others, retarding its action. These circumstances have led some to adopt a kind of intermediate opinion, and to regard the nervous influence as one of the conditions necessary for all muscular contraction, just as the due circulation of blood is: and to admit, at the same time, the separate existence of a *vis insita*. Sömmering[1] and Behrends[2] have, indeed, asserted that the cardiac nerves are not distributed to the tissue of the heart, but merely to the ramifications of the coronary arteries; and hence, that these nerves are not concerned in the motions of the organ, but only in its nutrition: but this special distribution is denied by Scarpa,[3] and the generality of anatomists.

Although the emotions manifestly affect the heart, direct experiments exhibit but little influence over it on the part of the nerves. This, indeed, we have seen, is one of the grounds for the doctrine of Haller. Willis[4] divided the eighth pair of nerves; yet the action of the heart persisted for days. Similar results followed the section of the great sympathetic. M. Magendie[5] states, that he removed, on several occasions, the cervical ganglions, and the first thoracic; but was unable to determine anything satisfactory from the operation, in consequence of the immediate death of the animal from such extensive injury. He observed, however, no direct influence on the heart.[6]

We have numerous examples of the comparative independence of the organ as regards the encephalon. Decapitated reptiles have lived for months; and anencephalous infants, or those born with part of the brain only, have vegetated during the whole period of pregnancy, and for some days after birth. M. Legallois[7] kept several decapitated mammalia alive; and maintained the heart in action, (having taken the precaution to tie the vessels of the neck for the purpose of preventing hemorrhage,) by employing artificial respiration, so as to keep up the conversion of venous into arterial blood, and thus insure to the heart a supply of its appropriate fluid. We find, too, that in fracture of the skull, in apoplexy, and congenerous affections, the functions of the

[1] Corpor. Human. Fabric., iii. § 32.

[2] Dissert. quà Demonstrat. Cor Nervis Carere, Mogunt., 1792; and in Ludwigii Script. Neurol. Min., i. 1.

[3] Tabulæ Neurologicæ, &c., Ticin., 1794.

[4] Cerebri Anat., cap. xxiv. in Oper., Genev., 1776.

[5] Précis, &c., ii. 401.

[6] Brachet, Physiologie Élémentaire de l'Homme, 2de édit., i. 142, Paris et Lyon, 1855.

[7] Sur le Principe de la Vie, p. 138.

heart are the last to be arrested. The result of his own experiments led Legallois to infer, that the power of the heart is altogether derived from the spinal marrow; and he conceived, that through the cardiac nerves it is influenced by that portion of the cerebro-spinal axis, and is liable to be affected by the passions because the spinal marrow is itself influenced by the brain. Dr. Wilson Philip[1] has, however, shown, that the facts do not warrant the conclusions; and has exhibited, by direct experiment, that the brain has as much influence as the spinal marrow over the motions of the heart, when the circumstances of the experiment are precisely the same. The removal of the spinal marrow, like that of the brain, if the experiment be performed cautiously and slowly, does not sensibly affect the motion of the organ,—the animal having been previously deprived of sensibility. In these experiments, the circulation ceased quite as soon without, as with, the destruction of the spinal marrow. Loss of blood appeared to be the chief cause of its cessation; and pain would have contributed to the same effect, if the animal had been operated on, without having been previously rendered insensible.

Sir Benjamin Brodie[2] inferred, from his experiments, that the influence of the brain is not directly necessary to the action of the heart; and that "when the brain is injured or removed, the action of the heart ceases only because respiration is under its influence, and if under these circumstances respiration be artificially produced, the circulation will still continue." Respiration is however only indirectly under the influence of the brain; the nervous centre of that function being seated in the medulla oblongata.

Mr. Clift,[3] the former conservator of the Museum of the Royal College of Surgeons of London, made a series of experiments to ascertain the influence of the spinal marrow on the action of the heart in fishes, and found, that it continues long after the brain and spinal marrow are destroyed, and still longer when the brain is removed without injury to its substance. Similar results were obtained by Treviranus on the frog, and by Saviole on the chick in ovo. Zinn and Ent, too, found, that after the destruction of the cerebellum, to which Willis ascribed its action, it continued to beat.

All these facts plainly exhibit, that, although the heart is *indirectly* influenced by the brain or spinal marrow, it is not *directly* acted upon by either one or the other, and that its action can be maintained for some time after the destruction of one or both, provided artificial respiration be kept up; and even this is unnecessary: it will continue to beat after it has been removed from the body. Dr. Dowler, of New Orleans,[4] saw the heart of the alligator beat for seven hours when its "annexing vessels" had been separated. In the case of the rattlesnake, Dr. Harlan[5] observed it, torn from the body, continue its contractions for ten or twelve hours; and in the monstrous fœtus, described by Dr.

[1] An Experimental Inquiry into the Laws of the Vital Functions, &c., p. 62, Lond., 1817.

[2] Philosophical Transactions for 1811, and Physiological Researches, p. 15, Lond., 1851.

[3] Philosoph. Transact. for 1815.

[4] Contributions to Physiology, p. 17, New Orleans, 1849.

[5] Medical and Physical Researches, p. 103, Philad., 1835.

T. Robinson,[1] its motion continued for some time after the auricles and ventricles had been laid open; the organ roughly handled, and thrown into a basin of cold water. We are compelled, then, if we do not admit the whole of the Hallerian doctrine of irritability, to presume, that there is something inherent in the structure of the heart, which enables it to contract and dilate, when appropriately stimulated: and it is not even necessary that this should be by the fluid to which it is habituated. It is certain, that the organ, when separated from the body, may be stimulated to contraction, by being immersed in warm water, or pricked with a sharp-pointed instrument; yet it is not possessed of ordinary sensibility. In Harvey's celebrated case, before referred to, the subject of which was presented to Charles II., the ventricles were touched; and "his most excellent majesty"—Harvey loyally observes—"as well as myself acknowledged that the heart was without the sense of touch; for the youth never knew when we touched his heart, except by the sight or the sensation he had through the external integument."[2] A similar experiment was made by Richerand on a physician from whom he had removed a portion of the pleura and several ribs. In a case, too, of ectopia cordis in a calf, Hering was able to knead the heart, as it were, (*malaxer le cœur*,) without occasioning any apparent uneasiness to the animal.[3]

In some experiments by Sir B. Brodie,[4] the heart was emptied of its blood, and still contracted and relaxed alternately. Similar experiments were instituted by Mr. Mayo,[5] and with like results,—from which he concludes, that the alternations of contraction and relaxation of the heart depend upon something in its structure. The conclusion seems, indeed, irrefutable, if we add to these evidences the results of certain experiments of Dr. J. Wiltbank,[6] and of Dr. J. K. Mitchell. After the brain and medulla spinalis of the *Testudo serpentaria*, *snapping-turtle* or *snapper* had been destroyed, the heart continued to beat for thirty-two hours and upwards. In 1823, Dr. Mitchell,[7] being engaged in dissecting a sturgeon—*Acipenser brevirostrum?*—took out its heart and laid it on the ground. After a time, it ceased to beat and was inflated with the breath, for the purpose of being dried. Hung up in this state, it began again to move, and continued for ten hours to pulsate regularly, though more and more slowly; and when last observed in motion, the auricles had become so dry as to rustle when they contracted and dilated. He subsequently repeated the experiment with the heart of a *Testudo serpentaria*, and found it to beat well under the influence of oxygen, hydrogen, carbonic acid, and nitrogen, thrown into it in succession. Water also stimulated it,—perhaps more strongly,—but made its substance look pale and hydropic, and, in *one minute*, destroyed action beyond recovery. A few years ago, (1845,) Dr. Mitchell repeated

[1] Amer. Journ. of the Med. Sciences, No. xxii., Feb., 1833.
[2] The Works of William Harvey, M. D., Sydenham Society's edit., p. 384.
[3] Bérard, Cours de Physiologie, iii. 652, Paris, 1851.
[4] Cooke's Treatise on Nervous Diseases, Introd., p. 61, Lond., 1820–23, Amer. edit., Boston, 1824.
[5] Outlines of Human Physiology, 4th edit., p. 46, Lond., 1837.
[6] The Philadelphia Journal of the Medical and Physical Sciences, ix. 361; Philad., 1824.
[7] American Journal of the Medical Sciences, vii. 58, Philad., 1830.

the experiment with the sturgeon, with the like results; and soon afterwards, Dr. F. G. Smith, junior,[1] experimented on the hearts of the sturgeon, frog, and snapping-turtle. The heart of one sturgeon contracted for twenty-two hours after its removal from the body; of another twelve hours; of the frog thirteen hours; and of the snapping-turtle 25¾ hours. The contractions of the last were arrested by putting the organ in warm water with the hope of increasing them. The heart of a sturgeon inflated by Dr. Smith, and kindly sent by him to the author, hung up in his library and kept moist, contracted and dilated for upwards of twenty hours.

It has been supposed, that when the heart is empty of blood, the contact of air with its cavities is the stimulus by which its irritability is excited, but Dr. John Reid[2] found—as Caldani, Wernlein and Kürschner had already done—when he placed a frog's heart in a state of activity under the receiver of an air-pump, that its action still continued after the receiver had been exhausted. Experiments, however, by F. Tiedemann[3] do not accord, in their results, with those of Dr. Reid; but confirm those of Fontana. He placed the heart, immediately after it was removed from a living frog, under the receiver of an air-pump, from which he exhausted the air: the pulsations of the heart became weaker and slower, and in thirty seconds ceased. After five minutes, the air was readmitted, and the pulsations were resumed; and this alternation was repeated several times; whilst another heart suspended in air continued in uninterrupted action for an hour. These experiments were repeated at the request of the author during the winter of 1849–50, by Drs. S. Weir Mitchell, and T. H. Bache, with analogous results. Whether these phenomena indicate that some change is produced physically in the organ by the altered density of the air; or that the presence of oxygen is necessary for its contraction may admit of a question. Dr. Brown-Séquard[4] has suggested that the action of the heart may be owing to the presence of carbonic acid in the blood. He admits, however, that if a frog be put under a receiver containing oxygen at 40° or 50° Fahr., after its nervous centres have been destroyed, its heart will continue to beat for a long time; whilst if it be placed in carbonic acid at the same temperature, the heart will beat very quickly at first, but soon cease. Castell[5] found, from numerous observations on the duration of the heart's action in different gases, that when frogs were placed in carbonic acid it ceased speedily, or in about six minutes; whilst in moist air, it continued for three hours, and when the air was exhausted, the pulsations could not be distinguished after ten minutes.

When the density of the air was augmented under the receiver, M. Tiedemann found, that the pulsations became quicker and stronger.

The heart is the generator of one of the forces that move the blood. This force has been the subject of much calculation, but the results have been so discordant as to throw discredit upon all mathematical

[1] Letter to the author, in Philadelphia Medical Examiner, for July, 1845, p. 393.
[2] Cyclop. of Anat. and Physiol., ii. 611, Lond., 1839.
[3] Müller's Archiv. für Anatomie. u. s. w., s. 490, Berlin, 1847.
[4] Experimental Researches applied to Physiology and Pathology, New York, 1853.
[5] Müller's Archiv., 1854, s. 226; and Canstatt's Jahresbericht, 1854, 1ter Bd., s. 151, Würzburg, 1855.

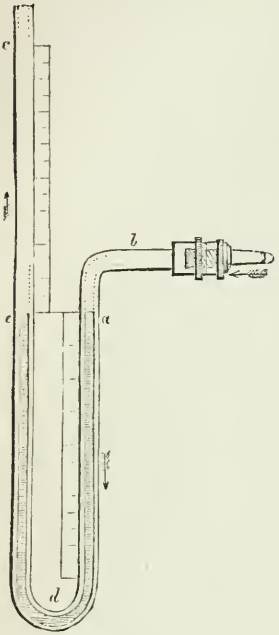
investigations on living organs; a circumstance, which renders it unnecessary to state the different plans that have been pursued in these estimations. Many of them are given in the elaborate work of Haller,[1] to which the reader, who may be desirous of examining them, is referred. Borelli[2] conceived the force exerted by the left ventricle to be equivalent to 180,000 pounds; Sénac[3] to 40; Hales[4] to 51·5 pounds; Jurin[5] to 15 pounds 4 ounces; whilst Keill[6] conceived it not to exceed from 5 to 8 ounces! The mode adopted by Hales has always been regarded the most satisfactory. By inserting a glass tube into the carotid of various animals, he noticed how high the blood rose in the tube. This he found to be, in the dog, 6 feet 8 inches; in the ram, 6 feet 5½ inches; in the horse, 9 feet 8 inches; and he estimated that in man it would rise as high as 7½ feet. Now, a tube, whose area is one inch square and two feet long, holds nearly a pound of water. We may therefore reckon the weight, pressing on each square inch of the ventricle, on a rough estimate, at three pounds and three-quarters, or four pounds; and if we consider with Michelotti, the surface of the left ventricle to be fifteen square inches, it will exert a force, during its contraction, capable of raising sixty pounds. Its extent is more frequently, however, estimated at 10 square inches, and the force developed would therefore, be forty pounds;[7] but this is, of course, a rude approximation. In such a deranging experiment, the force of the heart cannot fail to be modified; and it is so much affected by age, sex, temperament, idiosyncrasy, &c., that the attainment of accurate knowledge on the subject is impracticable. The indefinite character of our information on this matter is indeed sufficiently shown by the investigations of M. Poiseuille,[8] which led him to suppose, that the force with which the organ propels the blood into the human aorta is about 4 pounds, 3 ounces, and 43 grains; and if Valentin's estimate of the muscular force of the right ventricle being one-half that of the left be taken, it must propel the blood into the lungs with a force only equal to about two pounds, two ounces.

By means of an instrument, which, from its use, he terms *hæmadynamometer*, M. Poiseuille has endeavoured to show, that the blood is urged forward with as great a momentum in a small artery, far from the heart, as in any important branch near it. In other words, that there is a uniform amount of pressure exerted by the blood upon the coats of the arteries in every part of the body;—those in the immediate vicinity of the heart being distended by an equal force with those most remote from it. M. Poiseuille[9] made the experiment on the carotid, and muscular branch of the thigh of the horse, and notwithstanding the very great dissimilarity in the diameter of the two tubes, and in their distance from the heart, the displacement of the mercury

[1] Elementa Physiologiæ, lib. i. sect. iv. § 42, Lausann., 1757.
[2] De Motu Animalium, pars ii., Lugd. Bat., 1710.
[3] Traité de la Structure du Cœur, Paris, 1749.
[4] Statical Essays, &c., ii. 40, Lond., 1733.
[5] Philosophical Transactions for 1718 and 1719.
[6] Tentamina Medico-Physica, &c., Lond., 1718.
[7] Arnott's Elements of Physics, Amer. edit., pp. 447 and 461, Philad., 1841.
[8] Magendie's Journal de Physiologie, x. 241.
[9] Ibid., ix. 46.

was exactly the same in both. This inference, if correct,—and the experiments have been repeated by M. Magendie[1] and others with corresponding results,—is important in a therapeutical point of view, as it leads to the belief, that if it be desirable to lessen the quantity of the circulating fluid, it is of little consequence what vessel is opened. The experiments of Poiseuille and Magendie have not, however, been confirmed by Volkmann, and they do not appear to be in accordance with obvious hydrodynamic facts.[2]

Fig. 120.



Hæmadynamometer.

The hæmadynamometer employed by M. Poiseuille, consists of a bent glass tube, of the form represented in the marginal figure, filled with mercury in the lower bent part, *a*, *d*, *e*. The horizontal part *b*, provided with a brass head, is fitted into the artery, and a small quantity of a solution of carbonate of soda is interposed between the mercury and the blood, which is allowed to enter the tube with the view of preventing coagulation. When the blood is permitted to press upon the fluid in the horizontal limb, the rise of the mercury towards *e*, measured from the level to which it has fallen towards *d*, gives the pressure under which the blood moves.

Estimates by Valentin[3] as to the force of the heart make it even less than those of M. Poiseuille. He states, that in man and the higher mammalia, the absolute force exerted by the left ventricle is equal to $\frac{1}{50}$th of the weight of the body; and that by the right ventricle equal to $\frac{1}{100}$th of the same.

During the diastole of the ventricles, the pressure, as indicated by the instrument, is somewhat diminished. It was observed by Hales,[4] that the column of blood in a tube inserted into an artery fell after each pulsation. The pressure must obviously be augmented or diminished by anything that adds to or detracts from the heart's action; and it will be seen afterwards, that it is materially modified by the respiratory movements.[5]

b. *Circulation in the Arteries.*

The blood, propelled from the heart by the series of actions we have described, enters the two great bloodvessels;—the pulmonary artery from the right ventricle, and the aorta from the left; the former of which sends it to the lungs, the latter to every part of the system; and,

[1] Leçons sur le Sang, &c., or translation in Lond. Lancet, Sept., 1838 to March, 1839; and in Bell's Select Medical Library, p. 57, Philad., 1839.

[2] Todd and Bowman, The Physiological Anatomy and Physiology of Man, Pt. iv. p. 361, Lond., 1852, or Amer. edit., Philad., 1853.

[3] Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.

[4] Op. cit., ii. 2.

[5] Ludwig, in Müller's Archiv. für Anatomie, u. s. w., Heft iv. s. 242, Berlin, 1847.

in both vessels, it is prevented from returning into the corresponding ventricles by the depression of the semilunar valves. We have now to inquire into the circumstances, that act upon it in the arteries, and whether it be the contraction of the ventricle, which is alone concerned in its progression.

Harvey[1] and all the mechanical physiologists regarded the arteries as entirely passive in the circulation, and as acting like so many lifeless tubes; the heart being, in their view, the sole agent. We have, however, numerous reasons for believing that the arteries are concerned to a certain degree in the progression of the blood. If we open a large artery in a living animal, the blood flows in distinct pulses; but this effect gradually diminishes as the artery recedes from the heart, and ultimately ceases in the smallest ramifications;—seeming to show, that the force, exerted by the heart, is not the only one concerned. It is manifest, too, that if such was the case, the blood ought to flow out of the aperture, when the artery is opened, at intervals coinciding with the contractions of the organ; and that during the diastole of the artery no blood ought to issue.. This, however, is not the case, notwithstanding the authority of Bichat and some others is in its favour. The flow is uninterrupted; but in jets or pulses, coinciding with the contractions of the ventricles. Again, if two ligatures be put round an arterial trunk, at some distance from each other, and a puncture be made between the ligatures, the blood flows with a jet,—indicating that compression is exerted upon it; and if the diameter of the artery be measured with a pair of compasses, before and after puncturing the vessel, it will be found manifestly smaller in the latter case;—an experiment which shows the fallacy of a remark of Bichat,—that the force with which the arteries return upon themselves is insufficient to expel the blood they contain. An experiment of M. Magendie[2] exhibits this more clearly. He exposed the crural artery and vein in a dog, and passed a ligature behind the vessels, tying it strongly at the posterior part of the thigh, so that the blood could only pass to the limb by the artery, and return by the vein. He then measured, with a pair of compasses, the diameter of the artery; and on pressing the vessel between his fingers, to intercept the course of blood, it was observed to diminish perceptibly in size below the part compressed, and to empty itself of its blood. On readmitting the blood, by removing the fingers, the artery became gradually distended at each contraction of the heart, and resumed its previous dimensions.

These facts prove, that the arteries contract; but the kind of contraction has given occasion to discussion. Under the idea that their middle coat is muscular, it was conceived formerly, that they exert a similar action on the blood to that of the heart; dilating to receive it from that organ, and contracting to propel it forwards;—their systole being synchronous with that of the auricles and the diastole of the ventricles, and their diastole with that of the auricles and the systole of the ventricles. The principal reasons urged in favour of this view are;—the fact of the circulation being effected solely by the arteries in

[1] Exercitatio Anat. De Motu Cordis et Sanguinis, &c., Rotterd., 1648.
[2] Journal de Physiologie, i. 111; and Précis, &c., ii. 386.

acardiac fœtuses, and in animals that have no heart;—the assertion of MM. Lamure and Lafosse, that they noticed, in an experiment on the carotid artery, similar to that described above, that the vessel continued to beat between the ligatures;—the affirmations of Verschuir,[1] Bikker, Giulio, and Rossi,[2] Thomson,[3] Parry,[4] Hastings,[5] Wedemeyer, and numerous others, that when they irritated arteries with the point of a scalpel, or subjected them to the electrical and galvanic influences, they exhibited manifest contractility; and lastly, the fact, that the pulse is not perfectly synchronous in different parts of the body, which ought to be the case, were the arteries not possessed of distinct action.

The chief objection to the views founded on the muscularity of the middle coat was the want of evidence of the fact. In the anatomical proem to the function of the circulation it was stated, that this coat had not seemed to anatomists to consist of fibrous or muscular tissue; and that the experiments of MM. Magendie, Nysten, and others, had not been able to exhibit any contraction, on the application to it of the ordinary excitants of muscular irritability. The chemical analyses of Berzelius[6] and Young[7] also appeared to show, that the transverse fibres differ essentially from those of proper muscles. It has been suggested, however, that the older analyses may have been made on the largest arteries in which muscular fibres scarcely exist;[8] for histologists—as elsewhere shown—are now agreed, that, in the smaller arteries, more especially, the middle coat is partly composed of nonstriated or unstriped muscular tissue. Moreover, if any doubt existed in regard to the contractile action of the smaller arteries, it ought to be removed by the experiments of MM. E. and E. H. Weber,[9] accurate observers, which were made with the rotating magneto-electric apparatus upon the arteries of the mesentery of frogs between $\frac{1}{7}$th and $\frac{1}{17}$th of a Paris line in diameter. When vessels between these dimensions were exposed to the electric stream, they did not immediately respond to the irritation; but in a few seconds they began to contract, so that in from five to ten seconds their diameter was diminished one-third. If the stimulus was continued, the diminution of size went on until the diameter was reduced to one-third or even one-sixth of what it was originally, so that only a single row of blood-corpuscles could pass along the vessel, and at last became completely closed unless the stimulus was removed. They found, however, no change produced in the capillaries when the magneto-electric current was applied to them; but it appeared to cause an unusual adhesion of the corpuscles to each other, and to the parietes of the vessels, and a consequent stagnation of the circulating fluid in them. Nor did the larger arteries exhibit

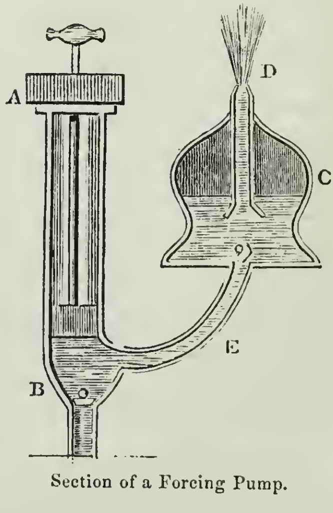
1 De Arteriar. et Venar. Vi Irritabili, &c., Gröning., 1766.
2 Elémens de Médec. Opérat., Turin, 1806.
3 Lectures on Inflammation, p. 83, Edinb., 1813; also, 2d Amer. edit., Philad., 1831.
4 On the Arterial Pulse, p. 52, Bath, 1816.
5 On Inflammation of the Mucous Membrane of the Lungs, p. 20, Lond., 1820.
6 View of the Progress of Animal Chemistry, p. 25, Lond., 1813.
7 An Introduction to Medical Literature, p. 501, Lond., 1813.
8 Kirkes and Paget, Manual of Physiology, p. 91, 2d Amer. edit., Philad., 1853.
9 Müller's Archiv. für Anatomie, u. s. w., H. ii. s. 232, Jahrgang, 1847.

any signs of contraction when the stream was directed to them. Similar results were obtained in analogous experiments by Kölliker.[1]

If an artery be exposed in a living animal, we observe none of that contraction and dilatation which is perceptible in the heart; although a manifest pulsation is communicated to the finger placed over it. The phenomena of the pulse will engage attention speedily. We may merely remark, at present, that the pulsations are manifestly more dependent upon the action of the heart than upon that of the arteries. In syncope, they entirely cease; and whilst they continue beneath an aneurismal tumour, because the continuity of the vessel is not destroyed, they completely cease beneath a ligature so applied around an artery as to cut off the flow of blood. Bichat attached an inert tube to the carotid artery of a living animal, so that the blood could flow through it: the same kind of pulsation was observed in it as in the artery. To this he adapted a bag of gummed taffeta, so as to simulate an aneurismal tumour: the pulsations were evidenced in the bag. If, again, arterial blood be passed into a vein, the latter vessel, which has ordinarily no pulsation, begins to beat; whilst, if blood from a vein be directed into an artery, the latter ceases to beat.[2]

Another class of physiologists have reduced the whole of the arterial action to simple elasticity; a property, which the yellow tissue that composes the proper membrane of the artery seems to possess in an unusual degree. Such is the opinion of M. Magendie.[3] "Admitting it to be certain," he remarks, "that contraction and dilatation occur in arteries, I am far from thinking, with some authors of the last century, that they dilate of themselves, and contract in the manner of muscular fibres. On the contrary, I am certain, that they are passive in both cases,—that is, that their dilatation and contraction are the simple effect of the elasticity of their parietes, put in action by the blood, which the heart sends incessantly into their cavity,"—and he farther remarks, that there is no difference, in this respect, between the large and small arteries. As regards the larger arteries, it is probable that this elasticity is the principal but not the only action exerted; and that it is the cause why the blood flows in a continuous, though pulsatory, stream, when an opening is made into them; thus acting like the reservoir of air in certain pumps. In the pump A B, represented in the marginal figure, were there no air-vessel C,

Fig. 121.



Section of a Forcing Pump.

[1] Kölliker and Siebold's Zeitschrift, 1849; and Brit. and For. Med.-Chir. Rev., July, 1850, p. 241.

[2] Adelon, art. Circulation, in Dict. de M decine, 1ère édit., v. 321, Paris, 1822, and Physiol. de l'Homme, edit. cit., iii. 380.

[3] Précis, &c., edit. cit., ii. 387

the water would flow through the pipe E at each stroke of the piston, but the stream would be interrupted. By means of the air-vessel this is remedied. The water, at each stroke, is sent into the vessel; the air contained in the air-vessel is thus compressed, and its elasticity thereby augmented; so that it keeps up a constant pressure on the surface of the water, and forces it out of the vessel through the pipe D in a nearly uniform stream.—Now, in the heart, the contraction of the ventricle acts like the depression of the piston; the blood is propelled into the artery in an interrupted manner, but the elasticity of the bloodvessel presses upon the blood, in the same manner as the air in the air-vessel presses upon the water within it; and the blood flows along the vessel in an uninterrupted, although pulsatory, stream.[1] There are many difficulties, however, in the way of admitting the whole of the action of the arteries in the circulation to be dependent upon simple elasticity. The heart of a salamander was opened by Spallanzani;[2] the blood continued to flow through the vessels for twelve minutes after the operation. The heart of a tadpole was cut out; the circulation was maintained for some time in several of the vascular ramifications of the tail. The heart of the chick in ovo was destroyed immediately after contraction; the arterial blood took a retrograde direction, and the momentum of the venous blood was redoubled. The circulation continued in this manner for eighteen minutes. Dr. Wilson Philip[3] states, that he distinctly saw the circulation in the smaller vessels, for some time after the heart had been removed from the body, and a similar observation was made by Dr. Hastings.[4] The last gentleman affirms, that in the large arterial trunks, and even in the veins, he has noticed, in the clearest manner, their contraction on the application of various stimulants, both chemical and mechanical. It is, moreover, well known, that if a small living artery be cut across, it soon contracts so as to arrest the hemorrhage;—that whilst an animal is bleeding to death the arteries will accommodate themselves to the decreasing quantity of blood in the vessels, and contract beyond the degree to which their elasticity could be presumed to carry them; and that after death they will again relax. Dr. Parry found, that an artery of a living animal, if exposed to the air, sometimes contracts in a few minutes to a great extent; in such case, only a single fibre of the artery may be affected, narrowing the channel in the same way as if a thread were tied round it.

The experiments that have been instituted for the purpose of discovering the dependence of the arterial action on the nervous system have likewise afforded evidences of their capability of assuming a contractile action, and have led to a better comprehension of cases of what have been called local *determinations* of blood. Dr. Philip found, that the motion of the blood in the capillaries is influenced by stimulants

[1] Haller, Elementa Physiologiæ, ii. 212, Lausan., 1760; Hales, Hæmastatics, p. 22, § 26, Lond., 1733; Hunter on the Blood, by J. F. Palmer, Amer. edit., p. 162, Philad., 1840; Sir C. Bell, Animal Mechanics, Library of Useful Knowledge, p. 44; and Todd and Bowman, The Physiological Anatomy and Physiology of Man, Pt. iv. p. 352, Lond., 1852; or Amer. edit., Philad., 1853.

[2] Experiments on the Circulation, &c., translated by R. Hall, Lond., 1801.

[3] An Experimental Inquiry into the Laws of the Vital Functions, Lond., 1817; and Lond. Med. Gazette, for March 25th, 1837, p. 952.

[4] Op. citat., p. 51.

applied to the central parts of the nervous system, which must be owing to these vessels, possessing a power of contractility, capable of being aroused to action by the nervous influence. The experiments of Sir Everard Home[1] are, however, more applicable, as they were directed to the larger arteries, respecting which the greatest doubts have been entertained. The carotid artery of a dog was laid bare; the par vagum and great sympathetic, which, in that animal, form one bundle, were separated from it by a flattened probe for one-tenth of an inch in length; the head and neck of the dog were then placed in an easy position, and the pulsations of the carotid artery were attended to by all present for two minutes, in order that the eye might be accustomed to their force in a natural state. The nerve passing over the probe was then slightly touched with caustic potassa. In a minute and a half, the pulsations of the exposed artery became more distinct. In two minutes, the beats were stronger; in four minutes, their violence was lessened; and in five minutes the action was restored to its natural state. The experiment was repeated with analogous results upon a rabbit. The par vagum was separated from the intercostal nerve; and when the former nerve alone was irritated no increase took place in the force of the action of the artery. "The carotid artery," says Sir Everard, "was chosen as the only artery in the body of sufficient size, that can be readily exposed, to which the nervous branches, supplying it, can be traced from their trunk. This experiment was repeated three different times, so as to leave no doubts respecting the result."

These experiments demonstrate, that, under the nervous influence, an increase or a diminution may take place in the contraction of an artery; and they aid us in the explanation of cases, in which the circulation has been accomplished where the heart has been altogether wanting or completely defective in structure. Sir Everard instituted farther experiments, with the view of determining whether heat or cold has the greater agency in stimulating the nerves to produce this effect upon the artery. The wrist of one arm was surrounded by bladders filled with ice; and after it had remained in that state for five minutes, the pulse of the two wrists was felt at the same time. The beats in that which had been cooled were found to be manifestly stronger. A similar experiment was now made with water, heated to from 120° to 130° of Fahrenheit. The pulse was found to be softer and feebler in the heated arm. When one wrist was cooled and the other heated, the stroke of the pulse of the cooled arm had much greater force than that of the heated one. These experiments were repeated upon the wrists of several young men and young women of different ages, with uniform results.

Lastly, we have remarked, and shall have occasion to refer to the matter again, that certain animals, that have no heart, have circulating vessels in which contraction and dilatation are perceptible. This is the case with the class *vermes* of Cuvier, and distinctly so in the *lumbricus marinus* or *lug*, the *leech*, &c. The fact has been invoked both by the believers in the muscular contractility of arteries, and by those who conceive the contractility to be peculiar; but our acquaintance

[1] Lectures on Comparative Anatomy, iii. 57, Lond., 1823.

with the intimate structure of the coats of the vessels in those animals is too imperfect for us to assert more than that they are manifestly contractile. In an interesting case of acardiac fœtus examined by Dr. Houston, of Dublin, it seemed impossible that the heart of a twin fœtus could have occasioned the movement of blood in the acardiac one; and hence that there must have been some power in the vessels of the latter—general, or capillary, or both—to effect the circulation through it. In most or all of these cases, however, a perfect twin fœtus exists, whose placenta is in some degree united with that of the imperfect one; and the circulation in the latter has usually been attributed to the influence of the heart of the former propagated through the placental vessels.

From these and other considerations, the majority of physiologists have admitted a contractile action, in perhaps all except the larger arterial trunks; and, at the present day, the most general and satisfactory opinion appears to be, that, in addition to the highly elastic property possessed by the middle coat, it is capable of being thrown into contraction through the organic muscular fibres, which exist in greater quantity in the small arteries than in the large; that, consequently in the larger vessels this contraction is little evidenced, the action of the artery being mainly produced by its elasticity; but that, in the smaller arterial ramifications, the contractility is more manifest; its great object being to regulate the quantity of blood to be distributed to a part; or to adjust the vessel to the amount of fluid circulating in it. To this contractility, necessarily connected with the life of the vessel, and which he considered to differ from both muscular contractility and simple elasticity, Dr. Parry[1] gave the name *tonicity*.

c. *Circulation through the Capillaries.*

The agency of the capillary vessels in the circulation has been a subject of contention. The opinion of Harvey, embraced by J. Müller,[2] was, that the action of the heart alone is sufficient to send the blood through the whole circuit; but we have seen, that, even when aided by the elasticity and contractility of the arterial trunks, the pulsations of that organ become imperceptible in the smaller arteries; and, hence, there is some show of reason for the belief, that in the capillary vessels the force may be entirely spent. Were we, indeed, to admit that the force of the heart is sufficient to send the blood through a single capillary circulation, it would be difficult to admit that it could send it through two—as in the portal circulation. Still, we can by no means accord with Professor Draper,[3] of New York, that "it is now on all hands conceded," that this powerful muscular organ—the heart—discharges "a very subsidiary duty."

Bichat regarded the capillaries as organs of propulsion, and alone concerned in returning the blood to the heart through the veins. Dr. Marshall Hall,[4] on the other hand, denies, that we have any proof of

[1] On the Arterial Pulse, p. 52, Bath, 1816.
[2] Handbuch, u. s. w., Baly's translation, p. 220, Lond., 1838.
[3] A Text-Book on Chemistry, p. 392, New York, 1846.
[4] A Critical and Experimental Essay on the Circulation, &c., p. 78, Lond., 1831, reprinted in this country, Philad., 1835.

irritability in the true capillaries; and Magendie[1] conceives the contraction of the heart to be the principal cause of the passage of the blood through those vessels. In support of this view he adduces the following experiment. Having passed a ligature round the thigh of a dog, so as not to compress the crural artery or vein, he tied the latter near the groin, and made a small opening into the vessel. The blood immediately issued with a considerable jet. He then pressed the artery between the fingers, so as to prevent the arterial blood from passing to the limb. The jet of venous blood did not, however, stop. It continued for some moments, but went on diminishing, and the flow was arrested, although the vein was filled through its whole extent. When the artery was examined during these occurrences, it was observed to contract gradually, and at length became completely empty when the course of the blood in the vein ceased. At this stage of the experiment, the compression was removed from the artery; the blood immediately passed into the vessel, and, as soon as it had reached the final divisions, began to flow again through the opening in the vein, and the jet was gradually restored. On compressing the artery again until it was emptied, and afterwards allowing the arterial blood to pass slowly along the vessel, the discharge from the vein took place, but without any jet: the jet was resumed, however, as soon as the artery was entirely free.

This experiment is not so convincing to us as it appears to have been to M. Magendie. The chief fact, which it exhibits, is the elastic, and probably contractile, power of the arteries. It might have been expected, *à priori*, under any hypothesis, that the quantity of blood discharged from the vein would hold a ratio to that sent by the artery; and, consequently, the experiment appears to us to bear but little on the question regarding the separate contractile action of the capillaries. It is difficult, indeed, to believe that such an action does not exist. In addition to the circumstance, already mentioned, of the absence of pulsation in the smaller arteries, almost every writer on the theory of inflammation has considered the fact of a distinct action of the capillaries established, and leaves to the physiologist the by no means easy task of proving it. Dr. Wilson Philip[2] placed the web of a frog's foot under the microscope, and distinctly saw the capillaries contract on the application of those stimulants that produce contraction of the muscular fibre. The results of Dr. Thomson's[3] experiments in investigating inflammation, as well as those of Dr. Hastings,[4] were the same. The facts, already referred to, regarding the continuance of the circulation in the minute vessels after the heart had been removed, as well as the observation of Dr. Philip, that the blood in the capillaries is influenced by stimulants applied to the central parts of the nervous system, are confirmatory of the same point. The experiments of Drs. Thomson, Philip, and Hastings, were repeated by Wedemeyer,[5] with

[1] Précis, &c., ii. 390.
[2] A Treatise on Febrile Diseases, 3d edit., ii. 17, London, 1813; and Medico-Chirurg. Transact., vol. xii. p. 401.
[3] Lectures on Inflammation, p. 83, Edinb., 1813.
[4] Op. citat.
[5] Untersuch. über die Kreislauf, u. s. w., Hannover, 1828; cited in Edinb. Med. and Surg. Journ., vol. xxxii.

great care. The circulation in the mesentery of the frog, and in the web of its foot, being observed through the microscope, it was evident, that no change occurred in the diameter of the small arteries, or in that of the capillaries, so long as the circulation was allowed to go on in its natural state; but as soon as excitants were applied to them, an alteration of their calibre was perceptible. Alcohol arrested the flow of blood without inducing much apparent contraction of the vessels. Chloride of sodium, in the course of three or four minutes, caused them to contract one-fifth of their calibre, which was followed by their dilatation, and a gradual retardation and stoppage of the blood. In a space of time varying from ten to thirty seconds, and sometimes immediately after the application of the galvanic circle, they contracted, some one-fourth, others one-half, and others three-fourths of their calibre. The contraction at times continued for a considerable period, occasionally for several hours; in other instances it ceased in ten minutes, and the vessels resumed their natural diameter. A second application of galvanism to the same capillaries seldom caused any material contraction. Schwann[1] likewise found, that when cold water was poured on the vessels of a frog, which had been previously in a warm atmosphere, the capillaries immediately contracted, but after a time regained their diameter. Farther, Mr. Hunter[2] found, on exposing arteries to the air, that they contracted so much as to occasion obliteration of their cavities; and it is well known, that when arteries—as the temporal—are divided, the hemorrhage is arrested by the spontaneous contraction of the divided vessel,—a contraction, which, as remarked by Dr. Carpenter, is much greater than could be accounted for by simple elasticity of tissue, and is more marked in small than in large vessels.[3]

All these facts prove the existence of a vital power in the capillaries, capable of modifying, to a considerable extent, the flow of blood through them.

Again:—the phenomena of local inflammation have been considered to favour this view of an independent action of the capillaries, in which there may be increased flow or retardation of the blood in a part, without the general circulation exhibiting augmented action or excitement. In the natural state, the vessels of the tunica conjunctiva covering the white of the eye receive little blood; but if any cause of irritation exists, as a grain of sand entering between the eyelids, blood is rapidly sent into them, giving the appearance that has been not inappropriately termed "blood-shot."[4] In the experiments of Kaltenbrunner,[5] which were fully confirmed on repetition, the blood in inflammation was at first observed streaming to the irritated part, in consequence of which the capillary vessels became distended; afterwards irregularity of circulation occurred in the gorged capillary

[1] Müller's Archiv., 1836, and Lond. Med. Gazette, May, 1837.

[2] A Treatise on the Blood, Inflammation, and Gunshot Wounds, Amer. edit., ii. 156, Philad., 1840.

[3] Principles of Human Physiology, Amer. edit., p. 259, Philad., 1855.

[4] Thomson's Lectures on Inflammation, Edinb., 1813.

[5] Experimenta circa Statum Sanguinis et Vasorum in Inflammatione, p. 23, Monach., 1826.

system; and subsequently complete arrest of the flow, and disorganization. These phenomena are of themselves sufficient to prove the existence of a separate action of the capillaries, and, taken in conjunction with other facts, are overwhelming. The blush of modesty, and the paleness of guilt, the hectic glow, and the translucency of congelation are circumstances that go to establish the same point.

The contractile power of the capillaries is doubtless modified by the condition of the nerves distributed to them, which, as we have seen, are observed to increase as the size of the vessels and the thickness of their coats diminish. Their influence is strikingly evinced in actions, that are altogether nervous, as in the flushed countenance occasioned by sudden mental emotion. By some, however, the whole capillary circulation has been ascribed to a motive faculty inherent in the corpuscles of the blood; whilst others, again, have asserted, that the "electro-galvanic power,"—or in other words—the nervous power, generated in the nervous system, and acting on the blood corpuscles through the parietes of the capillaries, is the immediate agent that directs the circulation in the capillaries. All this, however, enters into the inscrutable question,—what is the cause of life in the tissues.—a question to be agitated, but not solved, in a subsequent part of this volume.

But, not only has a vital power of contraction been conceded to the capillaries; it has been imagined, that they possess what the Germans call a Lebensturgor (*turgor vitalis*) or vital property of expansibility or turgescence. Such is the opinion of Hebenstreit[1] and of Prus;[2] and it has been embraced, in this country, by Professor Smith of Yale College; by his son, Professor N. R. Smith of Baltimore, in his excellent work on the "Arteries,"[3] and by Professor Hodge,[4] of Philadelphia. The idea has been esteemed to be confirmed by the fact of excitants having been seen under the microscope, by Hastings, Wedemeyer, and others, to occasion not only contraction but dilatation of the capillaries. The phenomena observed in the erectile tissues have likewise been considered to favour the hypothesis; but in answer to these arguments it may be replied, that the irregular excitation, produced in the parts by the application of powerful stimulants, might readily give occasion to an appearance of expansibility under the microscope, without our being justified in inferring, that these vessels possess an innate vital property of expansibility; and, in many of the cases, in which ammonia and galvanism were applied by Thomson, Hastings, Wedemeyer, and others, the action of contraction ought rather to be esteemed physical or chemical than vital. The results of the application of such excitants, as diluted alcohol, dilute solutions of ammonia and chloride of sodium, can alone be adduced as evidences of such vital action on the part of those vessels. The dilatation of the capillary system and of the smaller arteries, which has been remarked on the

[1] Dissert. de Turgore Vitali, Lips., 1795; Hildebrandt's Physiologie, Auflag. 5, § 84; and Tiedemann's Physiologie, trad. par Jourdan, p. 625, Paris, 1831.

[2] De l'Irritation, &c., Paris, 1825.

[3] Surgical Anatomy of the Arteries, 2d edit., Baltimore, 1835.

[4] North Amer. Med. and Surg. Journal, June, 1828.

contact of those agents, is not, as Oesterreicher[1] has remarked, the primary effect: it is the consequence of the afflux of blood to the irritated part, as was demonstrated, also, in the experiments of Kaltenbrunner on inflammation, to which allusion has been made. Lastly, attentive observation of the phenomena presented by the erectile tissues must lead to the conclusion, that turgescence of vessels is not the first link in the chain of phenomena; excitation is first induced in the nerves of the part,—generally through the influence of the brain, and thence, perhaps, through the sympathetic nerve,—and the afflux of fluid supervenes on this. The vital expansibility of the capillaries cannot, we think, be regarded as proved, or probable.

Professor Draper, of New York, maintains, that the great agency in the circulation of the blood is of a physical character; and is dependent upon the chemical relations of that fluid to the tissues with which it is brought in contact. On the principles of capillary attraction—he says—a liquid will readily flow through a porous body for which it has a chemical affinity; but it will refuse to flow through it, if it has no affinity for it. On this principle he explains why the arterial blood presses the venous before it in the systemic circulation, and why the reverse takes place in the pulmonic. "The systemic circulation takes place because arterial blood has a high affinity for the tissues, and venous blood little or none. The pulmonary circulation takes place because venous blood has a high affinity for atmospheric oxygen, which it finds in the air cells of the lungs; and arterial blood little or none. On the same principle we may explain the rise of sap in trees, the circulatory movements in the different animal tribes, and the minor circulations of the human system."[2] Dr. Dowler,[3] of New Orleans, whilst he earnestly combats the views of Professor Draper, is a strong advocate for the distinct action of the capillary vessels, and he adduces a number of striking experiments to establish his position. In perhaps one-fourth of the dissections which he records, the bodies were carried to the dissecting-room a few minutes after death. The external veins, chiefly those of the arms and neck, sometimes became distended; and when they were opened, the blood often flowed in a good stream, and was, at times, projected to the distance of a foot or more. In some cases, by putting a ligature around the arm, or by grasping it above the elbow, the blood was made to flow more freely, and by moving the muscles, as is done in ordinary bloodletting, the blood shot forth for some distance. Punctures in the middle of the subclavian discharged blood, which arose in a full stream, against gravity, two or three inches; sometimes forming an arch as it fell. The coronary veins discharged blood rapidly and "with surprising force." These dissections are considered by Dr. Dowler to show conclusively the independent action of the capillaries; "which in yellow fever, and other acute fevers, probably survives respiration and the heart's action; and when it ceases cadaveric hyperæmia takes place." Such is doubtless the fact; but it

[1] Versuch einer Darstellung der Lehre vom Kreislauf des Blutes, Nürnberg, 1826.

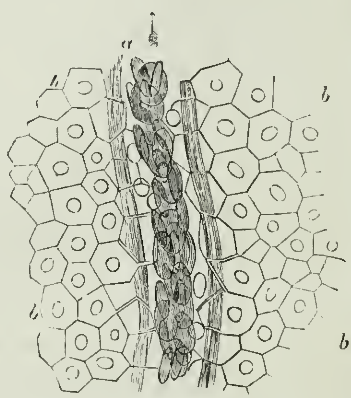
[2] A Text-Book of Chemistry, p. 392, New York, 1846; and On the Forces which Produce the Organization of Plants, chap. iii.

[3] Researches, Critical and Experimental, on the Capillary Circulation. (Reprinted from the New Orleans Medical and Surgical Journal.) January, 1849.

may still be questioned, whether anything more than the physical capillarity invoked by Professor Draper is concerned in the phenomenon. In a case observed by the author, and referred to elsewhere, blood flowed freely from the vessels of the brain, and coagulated fifteen hours after the cessation of respiration and circulation; and many similar cases are on record.

The circulation through the capillaries has long been an interesting topic of microscopic research. According to Wagner,[1] a magnifying power of from two to three hundred diameters is required to make out the particular details. The blood in mass, or in the larger channels, he says, is seen to flow more rapidly than in the smaller. Here the blood corpuscles advance with great rapidity, especially in the arteries, and with a whirling motion, and form a closely crowded stream in the middle of the vessel, without ever touching its parietes. With a little attention, a narrower and clearer, but always very distinct space is seen to remain between the great middle current of blood corpuscles and the walls of the vessel, in which a few white corpuscles, or what Wagner considers to be lymph corpuscles, are moved onwards, but at a much slower rate. These white corpuscles swim in smaller numbers in the transparent liquor sanguinis, and glide slowly, and in general smoothly, though they sometimes advance by fits and starts more rapidly, but with intervening pauses; and, as a general rule, at least ten or twelve times more slowly than the corpuscles of the central stream. The clear space, filled with liquor sanguinis and white corpuscles, is obvious in all the larger capillaries, whether arterial or venous, but ceases to be apparent in the smaller intermediate vessels which admit but one or two rows of blood corpuscles (Fig. 102). In these vessels, two sets of corpuscles proceed *pari passu;* but, according to Wagner, it is easy to see, that the blood corpuscles glide more readily onwards,—the white corpuscles seeming often to be detained at the bendings of vessels, and at the angles, where anastomosing branches are given off; here they remain adherent for an instant, and then suddenly proceed onwards. These phenomena are observed in every part of the peripheral systemic circulation; but an exception appears to exist in the pulmonic circulation; the capillaries there being filled with both kinds of corpuscles to their very walls.

Fig. 122.



Small Venous Branch, from the Web of a Frog's Foot, magnified 350 diameters.

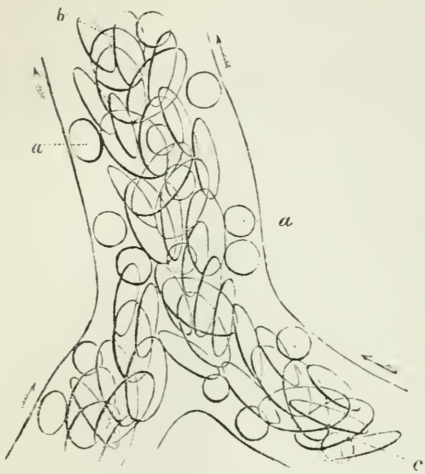
b, b. Cells of pavement epithelium, containing nuclei. In the space between the current of oval blood corpuscles, and the walls of the vessel, the round transparent lymph globules (?) are seen.

It is in this—the intermediate—part of the sanguiferous system, that most important functions take place. In the smallest artery we find

[1] Elements of Physiology, translated by R. Willis, § 122, Lond., 1842.

arterial blood; and in the smallest vein communicating with it blood always possessing venous properties. Between those points, a change must have occurred, the reverse of that which happens in the lungs. It is here, too—in the tissues—that nutrition, secretion, and calorification are effected. In the explanation of these functions, we shall find it impossible not to suppose a distinct and elective agency in the tissues concerned; and as it is by such agency, that the varying activity of the different functions is regulated, we are constrained to believe, that the capillary vessels may be able to exert a controlling influence over the quantity and velocity of the blood circulating in them. In disease, the agency of this system of vessels is an object of attentive study with the pathologist. To its influence in inflammation we have already alluded; but it is no less exemplified in the more general diseases of the frame,—as in the cold, hot, and sweating stages of an intermittent. Local, irregular capillary action is, indeed, one of the most common causes or effects of acute diseases, and this generally occurs in some organ at a distance from the seat of the deranging influence. It is a common and just observation, that getting the feet wet, and sitting in a draught of air, are more certain causes of catarrh than sudden atmospheric vicissitudes that apply to the whole body; and so extensive is the sympathy between the various portions of the system of nutrition, that the most diversified effects are produced in different individuals exposed to the same common cause; one may have inflammatory sore throat; another, ordinary catarrh; another, inflammation of the bowels; according to the precise predisposition, existing in the individual at the time, to have one structure morbidly affected rather than another; —but these are interesting topics, which belong more strictly to the pathologist.[1]

Fig. 123.



Large Vein of Frog's Foot, magnified 600 diameters.

b, c. Blood corpuscles. *a, a.* Lymph corpuscles (?) principally conspicuous in the clear space near the parietes of the vessel.

By the united action, then, of the heart, arteries, and capillary or intermediate system of vessels, the blood attains the veins. We have now to consider the circulation in these vessels.

d. *Circulation in the Veins.*

It has been already observed, that Harvey considered the force of the heart to be of itself sufficient to return the blood, sent from the left

[1] See, on the Capillary Circulation, William S. Savory, in Brit. and For. Med.-Chir. Rev., Jan., 1855, p. 390, and July, 1855, p. 12.

ventricle, to the heart; whilst Bichat conceived the whole propulsory effort to be lost in the capillaries, and the transmission of the blood along the veins to be entirely effected by the agency of the capillary system. It is singular, that an individual of such distinguished powers of discrimination should have been led into an error of this magnitude. It is a well-known principle in hydrostatics, that although water, when unconfined, can never rise above its level at any point, and can never move upwards; yet, by being confined in pipes or close channels of any kind, it will rise to the height from which it came. Hence the blood in the right auricle would stand at the same height as that in the left ventricle,—were they inanimate tubes. We need be at no loss, therefore, in understanding how the blood might attain the right auricle, when the body is erect, by this hydrostatic principle alone; but we have seen, that the force exerted by the heart, arteries, and capillary system is superadded to this, so that the blood would rise much higher than the right auricle, and consequently exert a manifest effort to enter it. It may be remarked, also, that the left ventricle is not the true height of the source, but the top of the arch of the aorta, which is more elevated by several inches than the right auricle. A similar view is embraced by Dr. Billing;[1] but Dr. Carpenter[2]—in commenting on the author's observations on this subject—suggests, that the influence of this hydrostatic force would scarcely be felt through the plexus of capillary vessels; "for the interposition of a system of tubes even of much larger calibre would be, by the friction created between the fluid and their walls, an effectual obstacle to the rapid ascent of a current, which had so slight an impetus as that derived from its previous fall." The author did not mean, however, to say more than that the blood "might attain" the right auricle by the hydrostatic force alone; he did not wish to convey the idea, that the circulation could be carried on without the aid of an additional force; but that a slight effort only on the part of the heart, arteries, and capillaries might be needed to enable the blood to perform its entire circuit. It is proper to add, that in the last editions of his valuable work, Dr. Carpenter has omitted those comments on the observations of the author.

Are we then to regard the veins as simple elastic tubes? This is the prevalent belief. Their elasticity is, however, much less than that of the arteries. Some physiologists have conceived them to possess contractile properties also. Such is the opinion of M. Broussais,[3] who founds it, in part, upon certain experiments by M. Sarlandière, already referred to, in which contraction and relaxation of the venæ cavæ of the frog were seen for many minutes after the heart was removed from the body. These pulsations of the venæ cavæ, and of the pulmonary veins in their natural state, have been seen by numerous observers—by Steno, Lower, Wepfer, Borrachius, Whytt, Haller, Lancisi, Müller, Marshall Hall, Flourens, J. J. Allison, and others.[4]

[1] First Principles of Medicine, Amer. edit., p. 36, Philad., 1842; 2d Amer. edit., Philad., 1851.

[2] Human Physiology, § 516, Lond., 1842.

[3] Traité de Physiol., &c., translat. by Drs. Bell and La Roche, p. 391, Philad., 1832.

[4] See the experiments of the last named gentleman, proving the existence of a venous pulse independent of the Heart and Nervous System, in Amer. Journal of the Medical Sciences, Feb., 1839, p. 306.

The experiments of Dr. Allison, in reference to the venæ cavæ and pulmonary veins, appeared to him to prove;—that they pulsate near the heart in the four classes of the vertebrata;—that in dying animals they pulsate long after the auricle and ventricle have ceased;—that they also beat even in quadrupeds for hours after they have been separated from the heart and from the body;—and that they can be stimulated to contract, either in or out of the body, by mechanical and galvanic agency, especially by the latter, after all motion has ceased for some time.

It has been deemed doubtful, however, whether the veins generally possess any contraction like that of the venæ cavæ and the pulmonary veins near the heart, for although irritated by galvanic and mechanical stimuli by Haller, Nysten, Müller, J. J. Allison, and others, no motion whatever could be detected in them. It has been before shown, however, that non-striated muscular fibres enter into their composition, and Gerber affirms, that the fibres of their middle coat bear a stronger resemblance to those of muscular tissue than do those of the corresponding coat of the arteries, which more resemble ordinary elastic fibres. In the veins of the bat's wing Mr. Wharton Jones[1] observed rhythmical contractions and dilatations, and that they were provided with valves, some of which completely, and others only partially, opposed the regurgitation of the blood. During the contraction the flow of blood in the vein was accelerated, and on the cessation of contraction the flow was checked, and there was a tendency to regurgitation. The action of the heart appeared to maintain the onward flow of blood during the dilatation of the vein, whilst the contraction of the vein was added to the action of the heart, and occasioned the acceleration.

In the experiments of Dr. Marshall Hall[2] on the circulation in the web of the frog's foot, he was almost invariably able to detect, with a good microscope, a degree of pulsatory acceleration of the blood in the arteries at each contraction of the heart; and he is disposed to conclude, that the natural circulation is rapid, and entirely pulsatory in the minute arteries, and slow and equable in the capillary and venous systems. But whenever the circulation was in the slightest degree impeded, the pulsatory movement became very manifest at each systole of the heart, and it was seen in all the three systems—arterial, capillary, and venous. He observed, that in the arteries there was generally an alternate, more or less rapid flow of the corpuscles at each systole and diastole of the ventricle; and that in the capillaries and veins the blood was often completely arrested during the diastole, and again propelled by a pulsatory movement during the systole;—all which he esteems conclusive proof, that the power and influence of the heart extend through the arteries to the capillaries, and through these to the veins, even in the extreme parts of the body. The experiments of Valentin[3] would seem, however, to show, that but little of the force of the left ventricle remains to propel the blood in the veins. He found, that the pressure of the blood in the jugular vein

[1] Philosophical Transactions, 1852, p. 158.
[2] Essay on the Circulation, ch. i., Lond., 1831, and Philad., 1835.
[3] Lehrbuch der Physiologie des Menschen, i. 477, Braunschweig, 1844.

of a dog, as estimated by the hæmadynamometer of Poiseuille, was not more than $\frac{1}{11}$th or $\frac{1}{12}$th of that in the carotid artery. In the upper part of the vena cava inferior, he could scarcely detect any pressure; almost the whole force of the heart having been apparently consumed during the passage of the blood through the capillaries:[1] still—as Messrs. Kirkes and Paget[2] suggest—slight as this remanent force might be, it would be enough to complete the circulation, inasmuch as although the spontaneous dilatation of the auricles and ventricles may not be forcible enough to assist the movement of blood in them, it is adapted to present no obstacle to the movement.

That the veins are possessed of elasticity is proved by the operation of bloodletting, in which a part of the jet, on puncturing the vein, is owing to the over-distended vessel returning upon itself; but that this property exists to a trifling extent only is shown by the varicose state of the vessels, which is so frequently seen in the lower extremities.

e. *Forces that propel the Blood.*

From the inquiry into the agency of the different circulatory organs in propelling the blood, it is manifest, that the action of the heart, the elasticity of the arteries, and a certain degree of contractile action in the smaller vessels more especially, a distinct action of the capillary vessels, and a slight elastic and perhaps contractile action on the part of the veins, may be esteemed the efficient motors. Of these, the action of the heart and capillaries, and the contraction of the arteries and veins, can alone be regarded as sources of motion, the elasticity of the vessels being simple directors, not generators of force. But there is another agency, which is probably more efficient than has been generally conceived. This is the *suction power* of the heart, or *derivation* as it has been termed, to which attention has been chiefly directed by Haller,[3] Wilson,[4] Carson,[5] Zugenbühler, Schubarth, Platner, Blumenbach,[6] and others; but which is not assented to by Oesterreicher,[7] Müller,[8] and others.[9] It is presumed, that the muscular fibres of the heart are mixed up with a large quantity of areolar tissue; and that whilst the contraction of the cavities is effected by the action of the muscular fibres, dilatation is produced by the relaxation of the contracted fibres, and the elasticity of the areolar tissue; so that when the heart has contracted, and sent its blood onwards, its elasticity instantly restores it to its dilated condition; a vacuum is formed, and the blood rushes in to fill it. This action has been compared by Dr. Bostock,[10] and by Dr. Southwood Smith,[11] Prof. Turner,[12] and others, to

[1] Magendie, Leçons sur les Phénomènes Physiques de la Vie, iii. 152, Paris, 1837.
[2] Manual of Physiology, 2d Amer. edit., p. 112, Philad., 1853.
[3] Elem. Physiol., ii. lib. vi.
[4] Enquiry into the Moving Powers employed in the Circulation of the Blood, Lond., 1784.
[5] Inquiry into the Causes of the Motion of the Blood, 2d edit., Lond., 1833.
[6] Institutiones Physiologicæ, § 126, Gotting., 1798.
[7] Lehre vom Kreislauf des Blutes, Nürnberg, 1826.
[8] Handbuch, u. s. w., Baly's translation, p. 173.
[9] Burdach, Physiologie als Erfahrungswissenschaft, iv. 270, Leipz., 1832.
[10] Physiology, 3d edit., p. 251, Lond., 1836.
[11] Animal Physiology, (Library of Useful Knowledge,) p. 83, Lond., 1829.
[12] Edinb. Medico-Chirurg. Transact., iii. 225.

that of an elastic gum bottle, which, when filled with water, and compressed by the hand, allows the fluid to be driven from its mouth with a velocity proportionate to the compressing force; but the instant the pressure is removed elasticity begins to operate, and if the mouth of the bottle be now immersed in water, a considerable quantity of that fluid will be drawn up into the bottle, in consequence of the vacuum formed within it. This power of elasticity in the tissues composing the parietes of the heart is the only one whose existence has been admitted as concerned in the phenomenon. Dr. Carpenter,[1] however—as before remarked—has suggested, whether there may not exist in muscle an active force of elongation, as well as an active force of contraction—arising from the mutual repulsion of particles whose natural contraction is the occasion of the shortening. The suggestion—it need scarcely be said—is altogether hypothetical.

The existence of this force is confirmed by Döllinger,[2]—who, when examining the embryos of birds, saw the blood advance along the veins, and the venous trunks pour it into the auricles at the moment they dilated to receive it; as well as by Dr. T. Robinson,[3] and M. Cruveilhier,[4] who were forcibly struck with the activity with which the diastole was effected, in the cases of monstrosity more than once referred to. Dr. Carpenter[5] thinks it very doubtful "how far the auricles have such a power of active dilatation as would be required for this purpose;" but the question need not regard the auricles. It is but necessary to suppose, that an action or power of dilatation exists in the ventricles; and this is now generally admitted. He farther remarks, that it has been shown experimentally by Dr. Arnott and others, that no suction power exerted at the farther end of a long tube, whose walls are as deficient in firmness as those of the veins are, can occasion any acceleration in a current of fluid transmitted through it; for the effect of the suction is destroyed at no great distance from the point at which it is applied by the flapping together of the sides of the vessel; but in answer to this it may be observed, that it remains to be shown, that such flapping of the sides would necessarily occur in the veins, which are living vessels, and constantly receiving blood from the capillaries under the action of vital forces.

Another accessory force, that has been invoked, is the suction power of the chest or *inspiration of venous blood*, as it has been termed. This is conceived to be effected by the same mechanism as that which draws air into the chest. The chest is dilated during inspiration; an approach to a vacuum occurs in it; and the blood, as well as the air, is forcibly drawn towards that cavity. On the other hand, during expiration, all the thoracic viscera are compressed; the venous blood is repelled from the chest, and the arterial blood reaches its destination with greater celerity, owing to the action of the expiratory muscles

[1] Principles of Human Physiology, Amer. edit., p. 249, (note), Philad., 1855.

[2] Denkschriften der Königl. Akademie der Wissenschaft. zu München, vii. 217; and Burdach, op. citat., p. 272.

[3] American Journal of the Medical Sciences, No. xxii.

[4] Gazette Médicale de Paris, 7 Août, 1841, p. 535; cited in Brit. and Foreign Medical Review, Oct., 1841, p. 535.

[5] Ibid., p. 276.

being added to that of the left ventricle. Haller,[1] Lamure,[2] and Lorry,[3] had observed, that the blood in the external jugular vein moves under manifestly different influences during inspiration and expiration. Generally, when the chest is dilated in inspiration, the vein empties itself briskly; becomes flat, and its sides are occasionally accurately applied against each other;—but during expiration it rises, and becomes filled with blood;—effects, which are more evident, when the respiratory movements are extensive. The explanation of this phenomenon by Haller and Lorry is the one given above.

To discover whether the same thing happens to the venæ cavæ, M. Magendie introduced a gum elastic catheter into the jugular vein, so as to penetrate the vena cava and even the right auricle:—the blood was observed to flow from the extremity of the tube at the time of expiration only. During inspiration, air was rapidly drawn into the heart, giving rise to the symptoms, elsewhere mentioned, which attend the reception of air into that organ. Similar results were obtained, when the tube was introduced into the crural vein in the direction of the abdomen. So far as regards the larger venous trunks, therefore, the influence of respiration on the circulation is sufficiently evidenced.[4]

It can be easily shown, by opening an artery of the limbs, that expiration—especially forced expiration, and violent efforts—manifestly accelerate the motion of arterial blood. In animals subjected to experiment, it is impracticable to excite either the forced expiration or violent effort at pleasure; but we can, as a substitute, compress the sides of the chest with the hands, according to the plan recommended by Lamure; when the blood will be found to flow more or less copiously in proportion to the pressure exerted. It occurred to M. Magendie, that this effect of respiration on the course of the blood in the arteries might influence the flow along the veins. To prove this, he passed a ligature around one of the jugular veins of a dog. The vessel emptied itself beneath the ligature, and became turgid above it. He then made a slight puncture with the lancet in the distended portion; and in this way obtained a jet of blood, which was not sensibly modified by the ordinary respiratory movements, but became of triple or quadruple the size, when the animal struggled. As it might be objected to this experiment, that the effect of respiration was not transmitted by the arteries to the open vein, but rather by the veins that had remained free, which might have conveyed the blood repelled from the vena cava towards the tied vein by means of anastomoses, the experiment was varied. The dog has not, like man, large internal jugular veins, which receive the blood from the interior of the head. The circulation from the head and neck is, in it, almost wholly confined to the external jugular veins, which are extremely large; the internal jugulars being little more than *vestiges*. By tying both of these veins at once, M. Magendie made sure of obviating, in great part, the reflux in question; but, instead of this double ligature diminishing the phenomenon under consideration, the jet became more closely connected with the respiratory

[1] Elementa Physiologiæ, tom. ii. lib. vi. sect. iv. § 8, Lausann., 1760.
[2] Mém. de l'Acad. des Sciences, pour 1749. [3] Magendie, Précis, &c., ii. 416.
[4] Poiseuille, in Magendie's Journal de Physiologie, viii. 272.

movement; for it was manifestly modified even by ordinary respiration, which was not the case when a single ligature was employed. From these and other experiments, he properly concluded that the turgescence of the veins must not be ascribed, with Haller, Lamure, and Lorry, simply to the reflux of the blood of the venæ cavæ into the branches opening directly or indirectly into them; but partly to the blood being sent in larger quantity into the veins from the arteries.[1] In the same manner are explained,—the rising and sinking of the brain, which, as will be observed in an after part of this volume, are synchronous with expiration and inspiration. During expiration, the thoracic and abdominal viscera are compressed; the blood is driven more into the branches of the ascending aorta, and is, at the same time, prevented from returning by the veins: owing to the combination of these causes, the brain is raised during expiration. In inspiration, all this pressure is removed; the blood is free to pass equally by the descending and ascending aorta; the return by the veins is ready, and the brain therefore sinks.[2] We can thus, also, explain why the face is red and swollen during crying, running, straining, and the violent emotions; and why pain is augmented in local inflammation of an extremity,—as in cases of whitlow; and when respiration is hurried or impeded by running, crying, &c. The blood accumulates in the part, owing to the compound effect of increased flow by the arteries, and impeded return by the veins. The same explanation applies to the production of hemorrhage by any violent exertion; and M. Bourdon[3] affirms, that he has always seen hemorrhage from the nose largely augmented during expiration; diminished at the time of inspiration; and arrested by prolonged inspiration;—a therapeutical fact of some interest.

Experiments with the hæmadynamometer by Poiseuille, and Ludwig,[4] confirm those mentioned above:—the column of mercury having been found to rise at each expiration, and to sink during inspiration.

It has often been remarked, too, that in forced and deep inspiration the force of the heart becomes so much diminished, that the pulse is very slow and feeble, and in some cases cannot be felt.[5] This phenomenon had attracted the attention of Weber[6] and Donders;[7] and has been the subject of numerous experiments by Dr. S. W. Mitchell.[8] All admit that an accumulation of blood takes place in the right side of the heart under such circumstances; and that such is the fact was demonstrated in the subject of a remarkable case of congenital absence

[1] Précis, &c., ii. 421.

[2] This motion of the brain must not be confounded with that which is synchronous with the contraction of the left ventricle; and is owing to the pulsation of the arteries at the base of the brain.

[3] Recherches sur la Méchanisme de la Respiration et sur la Circulation du Sang, Paris, 1820; see, also, Longet, Anatomie et Physiologie du Système Nerveux, pp. 777 and 779.

[4] Müller's Archiv. für Anatomie, u. s. w., Heft. iv. s. 242, Berlin, 1847.

[5] J. Müller, Lehrbuch der Physiolog., i. 198; and Todd and Bowman, The Physiological Anatomy and Physiology of Man, Pt. iv. p. 363, Lond., 1852, or Amer. edit., Philad., 1853.

[6] Müller's Archiv., 1851, p. 88; and Canstatt's Jahresbericht, 1851, s. 124.

[7] Henle and Pfeuffer's Zeitschrift, B. iii. and iv.; and Funke's Wagner's Lehrbuch der Physiologie, s. 296, Leipz., 1854.

[8] American Journal of the Med. Sciences, April, 1854, p. 387.

of the sternum, in which the movements of the heart were visible. It was distinctly seen, that when the young man held his breath the right auricle was made once and a half larger, and thus became engorged.[1] In prolonged and deep inspiration the flow of blood to the heart by the veins—as has been shown—is greatly promoted, whilst its export by the arteries is correspondingly diminished; and it is probable that the temporary cessation of the heart's action is the result of the consequent engorgement. These experiments sufficiently show, that a power exists of suspending the heart's action momentarily; and they throw some light on the extraordinary cases of suspended animation referred to elsewhere. (p. 403.)

It is manifest, then, that the circulation is modified by the movements of inspiration and expiration,[2]—the former facilitating the flow of blood to the heart by the veins, and the latter encouraging the flow from it by the arteries; and we shall see hereafter, that the dilatation of the chest,—which constitutes the first inspiration of the new-born child, —is the cause of the establishment of the new circulation; the same dilatation, which causes the entrance of air into the air-cells, soliciting the flow of blood, or the "inspiration of venous blood," as M. Magendie[3] has termed it. In a paper read before the Royal Society of London, in June, 1835, Dr. Wardrop,[4]—after remarking, that he considers inspiration as an auxiliary to the venous, and expiration to the arterial, circulation,—attempts, on this principle, to explain the influence exerted on the circulation, and on the action of the heart, by various modes of respiration, whether voluntary or involuntary, under different circumstances. Laughing, crying, weeping, sobbing, and sighing, he regards as efforts made with a view to effect certain alterations in the quantity of blood in the lungs and heart, when the circulation has been disturbed by mental emotions. The influence of ordinary respiration can, however, be trifling; yet it has been brought forward by Sir David Barry[5] as the efficient cause of venous circulation. His reasons for this belief are,—the facts just mentioned, regarding the influence of inspiration on the flow of blood towards the heart; and certain ingeniously modified experiments, tending to the elucidation of the same result. He introduced one end of a spirally convoluted tube into the jugular vein of an animal,—the vein being tied above the point where the tube was inserted,—and plunged the other into a vessel filled with a coloured fluid. During inspiration, the fluid passed from the vessel into the vein: during expiration, it remained stationary in the tube, or was repelled into the vessel. Dr. Bostock[6] remarks, that he was present at some experiments, which were performed by Sir David at the Veterinary College in London, and it appeared sufficiently obvious, that when one end of a glass tube was inserted either into the large

[1] Lancet, June 23, 1855; and Amer. Journ. of the Med. Sciences, Oct., 1855, p. 483.

[2] Dr. Clendinning's Report to the Brit. Association, 1839–40, in Lond. Med. Gazette, Nov. 13, 1840, p. 270.

[3] Précis, &c., ii. 416.

[4] On the Nature and Treatment of the Diseases of the Heart; with some new views of the Physiology of the Circulation, Lond., 1837.

[5] Experimental Researches on the Influence of Atmospheric Pressure upon the Circulation of the Blood, &c., Lond., 1826.

[6] Physiology, 3d edit., p. 330, note, Lond., 1836.

veins, into the cavity of the thorax, or into the pericardium,—the other end being plunged into a vessel of coloured water,—the water rose up the tube during inspiration, and descended during expiration. The conclusion of Sir David from these experiments is most comprehensive;—that "the circulation in the great veins depends upon atmospheric pressure in all animals possessing the power of contracting and dilating a cavity around that point, to which the centripetal current of their circulation is directed; and he conceives, that as, during inspiration, a vacuum is formed around the heart, the equilibrium of pressure is destroyed, and the atmosphere acts upon the superficial veins, propelling their contents onwards to supply the vacuum; but independently of other objections, there are a few that appear convincing against the sole agency of ordinary respiration in effecting venous circulation. According to Sir David's hypothesis, blood ought to arrive at the heart at the time of inspiration only; and as there are, on the average, seventy-two contractions of the heart for every eighteen inspirations; or four contractions, or—what is the same thing—four dilatations of the auricle for each respiration; one of these only ought to be concerned in the propulsion of blood, whilst the rest should be bloodless; yet we feel no difference in the strength of the four pulsations. It is clear, too, if we adopt Sir David's reasoning, that, of the four pulsations, two, and consequently two dilatations must occur during expiration, at which time the capacity of the chest is actually diminished; and, again, the respiratory influence cannot be invoked to explain the circulation in the fœtus or in aquatic animals. At the most, therefore, respiration can only be regarded as a feeble auxiliary in the circulation. In favour of his opinion of the efficiency of atmospheric pressure in causing the return of the blood by the veins, Sir David adduces the fact,—already referred to, under the head of Absorption, —that the application of an exhausted vessel over a poisoned wound prevents the absorption of the poison; but this, as we have seen, appears to be a physical effect, which would apply equally to any view of the subject.

In all these cases, the elastic resilience of the lungs, by contributing to diminish the atmospheric pressure from the outer surface of the auricles, may likewise, as suggested by Dr. Carson,[1] have some agency in soliciting the blood into these cavities; but the agency cannot be great. It has recently been suggested by Liebig,[2] that the fluids of the body, in consequence of the cutaneous and pulmonary transpiration, acquire a motion towards the skin and lungs; but it is not easy to see that this could have any important effect on the circulation.

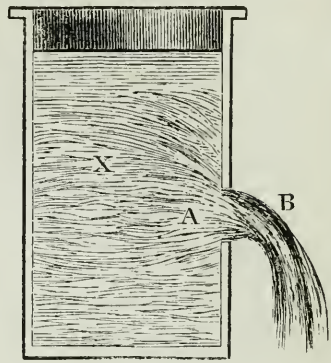
There is another circumstance of a purely physical nature, which may exert some influence upon the flow of the blood along the veins; the expanded termination of the venæ cavæ in the right auricle. To explain this, it is necessary to premise a detail of a few hydraulic facts. If an aperture A, Fig. 124, exist in a cistern X, the water will not issue at the aperture by a stream of uniform size; but, at a short distance

[1] Philosophical Transactions for 1820, and An Inquiry into the Causes of Respiration, &c., 3d edit., Liverpool, 1833.

[2] Researches on the Motion of the Juices in the Animal Body, by W. Gregory, M. D., p. 74, London, 1848.

from the reservoir, it will be contracted as at B, constituting what has been termed the *vena contracta.* Now, it has been found, that if a tube technically called an *adjutage* be attached to this aperture, so as to accurately fit the stream, as at A B, Fig. 125, as much fluid will flow from the reservoir as if the aperture alone existed.

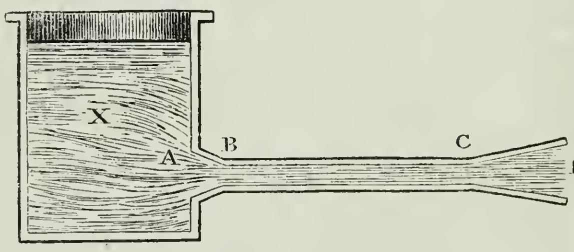
Fig. 124.



Vena Contracta.

Again, if the pipe B C be attached to the adjutage A B, the expanded extremity at A will occasion the flow of water from the reservoir to be greater than it would be if no such expanded extremity existed, in the ratio, according to Venturi, of 12·1 to 10; and if to the tube B C, a truncated conical tube C D be attached, the length of which is nearly nine times the diameter of C; and the diameter of C to that of D be as 1 to 8; the flow of water will be augmented in the proportion of 24 to 12·1; so that, by the two adjutages A B and C D, the expenditure through the pipe B C is increased in the ratio of 24 to 10. This fact,—the result of direct experiment, and so important to those who contract to supply water by means of pipes,—was known to the Romans. Private persons, according to Frontinus,[1] were in the habit of purchasing the right of delivering water in their houses from the public reservoirs, but the law prohibited them from making the conducting pipe larger than the opening allowed them in the reservoir, within the distance of fifty feet. The Roman legislature must, therefore, have been aware of the fact, that an adjutage with an expanded orifice, would increase the flow of water; but they were ignorant that the same effect would be induced beyond the fifty feet. A case—"The Schuylkill Navigation Company *against* Moore"—was tried in March term, 1837, before the Supreme Court in Pennsylvania, in which these hydraulic principles were involved. The defendant had conveyed to him by the plaintiffs a certain lot of ground, together with the privilege of drawing from the Schuylkill canal as much water as would pass through two metallic apertures of a size mentioned. He applied, however, to the aperture a conical tube or adjutage by which the flow of water was proved to have been

Fig. 125.



Vena Contracta.

[1] De Aquæductibus Urbis Romæ Commentarius, 190, 37, Patav., 1722.

greatly augmented. It was decided, that he had no right to increase the flow by such agency.[1]

Let us apply this law of hydraulics to the circulation. In the first place, at the origin of the pulmonary artery and aorta, there is a manifest narrowness, formed by the ring at the base of the semilunar valves: this might be conceived unfavourable to the flow of the blood along those vessels during the systole of the ventricles; but from the law, which has been laid down, the narrowness would occupy the natural situation of the vena contracta, and, therefore, little or no effect would be induced. The discharge would be the same as if no such narrowness existed. We have seen, again, that the vena cava becomes of larger calibre as it approaches the right auricle, and finally terminates in that cavity by an expanded aperture. This may have a similar effect with the expanded tube C D, Fig. 125, which doubles the expenditure.[2]

In making these conjectures,—some of which have been adduced by Sir Charles Bell,—it is proper to observe, that, in the opinion of some natural philosophers, the effect of the adjutage is entirely due to atmospheric pressure, and that no such acceleration occurs, provided the experiment be repeated *in vacuo.* Sir Charles Bell[3] conceives, that "the weight of the descending column in the reservoir being the force, and this operating as a *vis à tergo*, it is like the water propelled from the *jet d'eau*, and the gradual expansion of the tube permits the stream from behind to force itself between the filaments, and disperses them, without producing that pressure on the sides of the tube, which must take place, where it is of uniform calibre." It is on this latter view only, that these hydrostatic facts can be applied to the doctrine of the circulation.

In addition to the movements impressed on the blood by the parietes of the cavities in which it moves, it has been considered by many physiologists,—as by Harvey, Glisson, Bohn, Albinus, Rosa, Tiedemann, G. R. Treviranus,[4] Rogerson,[5] Alison,[6] and others,—to possess a power of automatic or self-motion. M. Broussais[7] asserts, that he has seen experiments,—originally performed by M. P. A. Fabre, which showed, that the blood, in the capillary system, frequently moves in an opposite direction to that given it by the heart,—repeated by M. Sarlandière on the mesentery of the frog. In these, the blood was seen to rush for some moments towards the point irritated; and, when a congestion had taken place there, they remarked, that the corpuscles took a different direction, and traversed vessels which conveyed them in an opposite course; and, a few seconds afterwards, they were again observed to return with equal rapidity to the point from which they had been repelled. Tiedemann[8] has collected the testimonies of various

[1] Reports of Cases adjudged in the Supreme Court of Pennsylvania, in the Eastern District, by Thomas I. Wharton, vol. ii. p. 477, Philadelphia, 1837.

[2] Venturi, Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798.

[3] Animal Mechanics, p. 40, in Library of Useful Knowledge, Lond., 1829.

[4] Tiedemann, Traité Complet de Physiologie de l'Homme, traduit par Jourdan, i. 348, Paris, 1831.

[5] A Treatise on Inflammation, &c., Lond., 1832.

[6] Edinburgh Med. and Surg. Journal for Jan., 1836.

[7] Traité de Physiologie, &c., translated by Drs. Bell and La Roche, 3d edit., p. 374, Philad., 1832.

[8] Op. citat.

individuals on this point. Haller,[1] Spallanzani,[2] Wilson Philip,[3] G. R. Treviranus,[4] and others, have remarked, by the aid of the microscope, that the blood continued to move in the vessels of different animals, but chiefly of frogs, for some time after the great vessels had been tied, or the heart itself removed;—a fact which Tiedemann, also, often witnessed. C. F. Wolff,[5] Rolando,[6] Döllinger and Pander,[7] Prévost and Dumas,[8] Von Baer,[9] and others,[10] saw blood corpuscles in motion in the incubated egg, before the formation of either vessels or heart; and Hunter, Gruithuisen, and Kaltenbrunner observed,—in the midst of the areolar tissue of inflamed parts, in tissues undergoing regeneration, and during the cicatrization of wounds,—bloody points placed successively in contact with each other, forming small currents, which represented new vessels, and united to those already existing. The fact, indeed, that the embryo forms its own vessels, and that blood in motion can be detected before vessels are *in esse*, is a sufficient proof,—were there no other,—that the corpuscles of the blood possess the faculty of motion, either in themselves, or by virtue of an attraction exerted upon them by the solid parietes in which they move. Müller[11] thinks the idea of spontaneous motion in a fluid, independently of attraction or repulsion from the sides of another object, is inconceivable; and as Tiedemann[12] has remarked, if we admit this faculty in animals provided with a heart, the progression of the blood must be mainly owing to that viscus; for, after the heart ceases to act, the circulation is soon arrested. The blood, too, only remains fluid, and possesses the faculty of motion, whilst it is in connexion with the living body. When taken from the vessel in which it circulates, it soon coagulates, and loses its motive power. This motion has, by some,—and, according to Brandt,[13] not without grounds,—been presumed to be owing to electro-chemical agency.

Burdach[14] has properly observed, that the old but perfectly correct saying, "*ubi stimulus ibi affluxus*," means nothing more than that where the vital activity of an organ is augmented, more blood will be drawn to it; whence it naturally follows, that the progression of blood in the capillaries must be, in some measure, dependent on the activity of the vital manifestations in the tissue. It has been already shown, that if the capillary action be excited by stimulants, a greater flow of blood takes place into that system of vessels; and as the functions of

[1] Oper. Minor., i. 115, sect. 8.
[2] Exper. on the Circulation, &c., in Eng. by R. Hall, Lond., 1801.
[3] Philos. Transact., 1815; and Medico-Chirurg. Trans., vol. xii.
[4] Vermischte Schriften, i. 102.
[5] Theoria Generationis, Hal., 1759.
[6] Dizionario Periodico di Medicina, Torino, 1822–1823.
[7] Dissert. sist. Hist. Metamorphoseos quam Ovum Incubatum prioribus quinque Diebus subit, Wirceb., 1817.
[8] Annales des Sciences Naturelles, tom. xii. p. 415, Dec., 1827.
[9] Ueber die Entwickelungsgeschichte der Thiere, u. s. w., Th. i. Königsberg, 1828.
[10] Allen Thomson, On the Formation of New Bloodvessels, Edinb., 1832; and art. Circulation, in Cyclopædia of Anat. and Physiology, p. 7, Lond., 1836.
[11] Handbuch, u. s. w., Baly's translation, p. 224, Lond., 1838.
[12] Op. cit., p. 349.
[13] Art. Blut, in Encyclopäd. Wörterb. der Medicinisch. Wissenschaft. v. 596, Berlin, 1830.
[14] Die Physiologie als Erfahrungswissenschaft, &c., Band. iv., Leipz., 1832.

nutrition and secretion are accomplished by that system, it is obvious, that any increase in the activity of those functions must attract a larger afflux of fluids, and, in this manner, modify the circulation independently of the heart and larger vessels. But this, again, can have but a subordinate influence on the general circulation.

Lastly, M. Raspail[1] resolves the whole of the circulation, as he does other functions, into a double action of *aspiration* and *expiration* by the tissues concerned. As the blood is the bearer of life to every part of the organism, and of nourishment and reparation to the organs, —to prevent its destination being annulled, a part of the fluid, he says, must be absorbed by the surfaces, which it bathes: these surfaces must attract nutritive juices from the blood, and they must return to the blood the refuse of their elaboration,—in other words, they must *aspire* and *expire*. Now, this double function cannot take place without the fluid being set in motion, and this motion must be the more constant and uniform as the double function is inherent in every molecule of the surface of the vessels. In this way he accounts for the mercury, placed in a tube communicating with an artery, being kept at the same height near to, or at a distance from, the heart; because, he says, it is not the action of the heart which supports it, but the action of the parietes of the vessels. Every surface, which aspires, provided it is flexible, must be, in its turn, he conceives, attracted by the substance aspired, and, consequently, by the act of aspiration alone, the motions of systole and diastole of the heart and arteries may be explained. When their inner parietes aspire—or assimilate the fluid,—the heart will contract; when, on the contrary, they expire,—owing to the mutual repulsion between the heart and the fluid, the former dilates; and, as the movements of the heart are energetic on account of its size, its movements will add to the velocity of the circulation in the arteries, which will, therefore, besides their proper actions of aspiration and expiration, present movements isochronous with the pulsations of the heart. "Add to this accessory cause of arterial pulsations the movements impressed by the aerial aspiration, which takes place in the lungs, and the circulation of the blood will no longer present insurmountable problems."

All this, it need scarcely be said, is ingenious; but nothing more.

f. *Accelerating and Retarding Forces.*

The above are the chief accelerating causes of the circulation. There are others, that at times accelerate, and at times retard; and others, again, that must always be regarded as impeding influences. All these are of a physical character, and applicable as well to inert hydraulic machines as to the pipes of the human body.

1. *Friction* always acts as a retarding force. That which occurs between a solid and the surface on which it moves, can be subjected to calculation, but not so with a fluid, inasmuch as all its particles do not move equally: whilst one part is moving rapidly, another may be stationary, moving slowly, or even in a contrary direction, as is seen in rivers, where the middle of the stream always flows with greater velo-

[1] Chimie Organique, p. 364, Paris, 1833.

city than the sides. The same thing happens to water flowing through pipes; the water, which is in contact with the sides of the pipe, moves more slowly than that at the centre. This retarding force is much diminished by the polished state of the inner surface of the bloodvessels, as is proved by the circumstance, that if we introduce an inert tube into an artery, the blood will not flow through it for any length of time. M. Poiseuille[1] infers, from his investigations, that a still layer of serum lines the interior of the capillary vessels, which may have some effect in retarding the blood globules in their progress through the intermediate system. Yet the viscosity of the blood, within certain limits, would seem to be important to enable it to pass through the capillary system. M. Magendie, indeed, pronounces it to be an indispensable condition for its free circulation through the capillaries.[2]

2. *Gravity* may either be an active or retarding force, and is always exerting itself, in both ways, on different sets of vessels. If, for example, the flow of blood to the lower extremity by the arteries is aided in the erect attitude by the force of gravity, its return by the veins is retarded by the same cause. The pulse of a person in health beats slower when he is in the recumbent, than in the erect, attitude. This is owing to there being no necessity for the heart to make use of unusual exertions for the purpose of forcing the blood, against gravity, towards the upper part of the body. In therapeutics, the physician finds great advantage from bearing this influence in mind; and, hence, in diseases of the head,—as in inflammation of the brain, in apoplectic tendency, ophthalmia, &c.,—he directs the patient's head to be kept raised; whilst in uterine affections the horizontal posture, or one in which the lower part of the body is raised even higher than the head, is inculcated; and in ulcers or inflammatory diseases of the lower extremities, the leg is recommended to be kept elevated. Every one, who has had the misfortune to suffer from whitlow, has experienced the essential difference in the degree of pain produced by position. If the finger be held down, gravity aids the flow of blood by the arteries, and retards its return by the veins: the consequence is turgescence and painful distension; but if it be held higher than the centre of the circulation, the flow by the arteries is impeded, whilst its return by the veins is accelerated, and hence the marked relief afforded.

3. *Curvatures.*—Besides friction, the existence of curvatures has considerable effect on the velocity and quantity of the fluid passing through pipes. A jet does not rise as high from the pipe or adjutage of a reservoir, if there be an angular turn in it, as if the bend were a gradual curve or sweep. The expense of force, produced by such curvatures in arteries, is seen at each contraction of the ventricle,—the tendency in the artery to become straight producing an evident movement, which has been called *locomotion of the artery*, and has been looked upon, by some, as the principal cause of the pulse. This motion is, of course, more perceptible the nearer to the heart, and the greater the vessel; hence it is more obvious at the arch of the aorta; and we can now understand why this arch should be so gradual. There is a good ex-

[1] Biblioth. Universelle, Nov., 1835.
[2] Lectures on the Blood, edit. cit., p. 102, Philad., 1839.

ample of the force used in this effort at straightening the artery, in the case of the popliteal artery, when the legs are crossed, and a curvature is thus produced. The force is sufficient to raise a weight of upwards of fifty pounds at each contraction of the ventricle, notwithstanding it acts at the extremity of so long a lever. This fact is sufficient to exhibit the inaccuracy of the notion of MM. Bichat and Bricheteau,[1] that the curvatures in the arteries can have no effect in retarding the flow of blood. Such could only be the case, Bichat thinks, if the vessels were empty at each systole.

4. *Anastomoses.*—The anastomoses of vessels have, doubtless, also some influence on the course of the blood; but it is impossible to appreciate it. The superficial veins are especially liable to have the circulation impeded by compression in the different postures of the body; but by means of the numerous anastomoses if the blood cannot pass by one channel, it is diverted into others. Although, however, a forcible compression may arrest or retard the flow by those vessels, a slight degree of support prevents the vein from being dilated by the force of the blood passing into it, and thus favours its motion. The constant pressure of the skin hence facilitates the circulation through the subcutaneous veins, and if, by any means, the pressure be diminished, especially in those parts in which the blood has to make its way against gravity—as in the lower extremities—varices or dilatations of the vessels supervene, which are remedied by the mechanical compression of an appropriate bandage.

Attempts have been made to calculate the velocity with which the blood proceeds in its course; and how long it would take for a blood corpuscle, setting out from the left side of the heart, to attain the right side. It is clear, that the data are, in the first place, totally insufficient for any approximation. We know not the exact quantity of blood contained in the vessels;—the amount sent into the artery at each contraction of the ventricle; the relative velocity of the arterial, venous, and capillary circulations;—and, if we knew them at any one moment, they are liable to incessant fluctuations, which would preclude any accurate average from being deduced. Were these circumstances insufficient to exhibit the inanity of such researches, the varying estimates of different observers would establish it. These assign the time occupied in the circulation from two minutes to fifteen or twenty hours! Moreover, the distances which the corpuscles have to traverse must be various. In the heart, the passage from one side to the other by the coronary vessels is very short; whilst if the blood has to proceed to a remote part of the body, the distance is considerable.

Were we to regard the vascular system as forming a single tube;—by knowing the weight of the blood and the quantity which the left ventricle is capable of sending forward at each contraction, we could calculate with facility the period that must elapse before an amount equal to the whole mass is distributed. Thus, if we estimate, with many physiologists, the quantity propelled forward at each contraction of the ventricle to be two ounces; and the whole mass of blood to be

[1] Clinique Médicale, p. 145, Paris, 1835; or the author's translation in his American Medical Library, Philad., 1837.

30 pounds, it will require, on an average, about 240 beats of the heart to send it onwards; which can be accomplished in little more than 3 minutes, yet, notwithstanding the absence of the requisite data, a modern writer has gone so far as to affirm the average velocity of the blood in the aorta to be about eight inches per second; whilst "the velocity in the extreme capillaries is found to be often less than one inch per minute!" A similar estimate was made by Dr. Young:[1] Hales[2] estimated the velocity of the blood, leaving the heart at 149·2 feet per minute, and the quantity of blood passing through the organ every hour at twenty times the weight of the blood in the body; but the judicious physiologist knows well, that in all operations, which are, in part, of a vital character, the results of every kind of calculation must be received with caution. In the larger animals, as the whale, the quantity of the fluid circulating in the aorta must be prodigious. Dr. Hunter, in his account of the dissection of a whale, states that the aorta was a foot in diameter, and that ten or fifteen gallons of blood were probably thrown out of the heart at each stroke; so that this vessel is, in the whale, actually larger than the main pipe of the old water-works at London Bridge; and the water, rushing through the pipe, it has been conceived, had less impetus and velocity than that gushing from the heart of this leviathan.[3]

But the highest of these estimates, as to the velocity of the circulatory current, is probably far beneath the truth, inasmuch as experiments have shown, that substances introduced into the venous circulation may be detected in the remotest parts of the arterial circulation in animals larger even than man in less than thirty seconds. Ten seconds after having injected a solution of nitrate of baryta into the jugular vein of a horse, Dr. Blake,[4] formerly of Saint Louis, drew blood from the carotid of the opposite side: after allowing this to flow for five seconds, he received the blood that flowed during the next five seconds into another vessel; and that which flowed after the twentieth second, by which time the action of the heart had stopped, was received into a third vessel. No trace of baryta could be detected in the blood that flowed between the tenth and fifteenth seconds; but it was discovered in that which flowed between the fifteenth and twentieth. In a dog, the poisonous effects of strychnia on the nervous system appeared in twelve seconds after injection into the jugular vein; in a fowl in six and a half seconds; and in a rabbit in four and a half seconds,—the interval being in an inverse ratio to the velocity of their respective circulations. From the results of these and other experiments, Dr. Carpenter thought it difficult to resist the conclusion, that some other force than the contractions of the heart must have a share in producing the movement of the blood through the vessels.[5] If, however, we adopt the estimate of the average quantity of blood dis-

[1] An Introduction to Med. Literature, p. 609, Lond., 1813.

[2] Statical Essays, vol. ii. p. 40, Lond., 1733.

[3] Paley's Natural Theology; and Animal Physiology, p. 75, Library of Useful Knowledge, Lond., 1829.

[4] Edinb. Med. and Surg. Journal, Oct., 1841; St. Louis Medical and Surgical Journal, Nov. and Dec., 1848; and American Journal of the Medical Sciences, p. 100, July, 1849.

[5] Human Physiology, § 491, Lond., 1842.

charged by the left ventricle at each contraction, as given by Valentin,[1]—(oz. 5·3,) and still more that given by Volkmann (oz. 6·2)—a part of the difficulty is removed. According to the data of the former thirty pounds of blood would require 90 contractions of the ventricle, which would be accomplished in about a minute and a third,—Mr. Paget says in from 43¾ to 62⅔ seconds,—the discordance being owing to the varying estimates as to the quantity of blood in the body. If we take the estimate of the amount of blood by Dr. Blake (page 357), it could be accomplished in from 53 to 60 contractions of the ventricle, or in from 44 to 50 seconds. Valentin's estimate of the quantity sent out at each contraction is probably, however, too high:—three ounces may be nearer the mark.

With this velocity of the general circulation, it seems at first difficult to comprehend its slowness of progression in the capillary vessels, which in the frog, according to Valentin,[2] from many careful micrometric examinations, is from 0·938 to 1·4 English inch per minute. In the small veins, he says, it is about ⅛th faster. These velocities, as Mr. Paget[3] remarks, agree nearly with those of Hales,[4] who estimated the velocity at an inch in a minute and a half; and more nearly still with those of Weber, who found it 1¼ inch per minute. On examining with the microscope the circulation in the tongue of the frog, the blood is observed streaming with immense velocity through the larger vessels, whilst in those that admit but a single file of red corpuscles, the motion is as slow as described by those observers.

It has been well remarked by Messrs. Kirkes and Paget,[5] that the speed at which the blood may be seen moving in transparent parts is not opposed to the calculations of Valentin and others; inasmuch as, although the movement through certain capillaries may be very slow, the length of capillary through which any portion of blood has to pass is very small. "If we estimate that length at the tenth of an inch, and suppose the velocity of the blood therein to be only one inch per minute, then each portion of blood may traverse its own distance of the capillary system in about six seconds. There would thus be plenty of time left for the blood to travel through its circuit in the larger vessels, in which the greatest length of tube that it can have to traverse in the human subject does not exceed ten feet." The observations of Volkmann,[6] on the mesenteric arteries of the dog make the rate of flow about ·03 inch per second or 1·8 per minute; and comparing this with the rate in the larger arteries, which appeared to be, on the average, 11·8 inches per second, it is calculated by him, that the aggregate area of the capillaries must be nearly four hundred times that of the arterial trunks, which supply them. The instrument with which he measured the velocity of the current in the vessels and to which he gave the name *hæmodrometer* consists of a glass tube, fifty-two inches long, bent into the form of a hair pin, and containing water, which he substituted for a segment of the bloodvessel, the velocity of whose blood current he was desirous of estimating. The

[1] Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.
[2] Op. cit. [3] Loc. cit. [4] Op. citat., ii. 68.
[5] Manual of Physiology, 2d Amer. edit., p. 117. Philad., 1853.
[6] Hæmodynamik, s. 184, 204, and Carpenter, Principles of Human Physiol., Amer. edit., p. 269, Philad., 1855.

column of blood from the heart pushes the column of water before it, without much admixture of the fluids taking place; and the distance through which it passes in a given time is a measure of its velocity.[1]

The velocity of the circulating fluid in the smaller arterial vessels is generally thought to be less than in the larger; and their united calibres to be much greater than that of the trunk with which they communicate. Were this the case, the diminution of velocity would be in accordance with a law of hydrodynamics;—that when a liquid flows through a full pipe, the quantity which traverses the different sections of the pipe in a given time must be every where the same; so that where the pipe is wider the velocity diminishes: and, on the contrary, where it is narrower the velocity increases. This would not seem, however, to be consistent with the calculations of Dr. T. Young, and Weber, and the experiments of M. Poiseuille, already referred to, which Drs. Spengler[2] and Valentin[3] concur in, but Volkmann and Ludwig oppose,[4] which show, that the pressure exerted on the blood in different parts of the body—as measured by the column of mercury, which the blood in different arteries will sustain—is almost exactly the same.

The cause of error in the common belief,—that the capacity of the arterial tubes increases in proportion to their distance from the heart,—has been explained by Mr. Ferneley[5] and others. It is true, he observes, that the sum of the diameters of the branches is considerably greater than that of the trunk. Thus a trunk, 7 lines across, may divide into two branches of 5 lines each; or a trunk of 17 into three branches of 10, 10, and 9½; but when their areas are compared, which is the only mode of arriving at their calibres, the correspondence is as close as can be reasonably expected, when the nature of the measurement is taken into account. In the first case, the area of the trunk is represented by the square of 7—that is 49; whilst the area of each branch will be 25, and the sum of the two will be 50. In the second instance, the area of the trunk will be 17 squared, or 289; whilst that of the branches is the sum of 100, 100, and 90½, making 290½. This will be more strikingly seen from the following table of measurements of the mesenteric artery of the sheep by Mr. Ferneley.

	Trunks.		Branches.	
	Diameter.	Square of Diameter.	Diameter.	Sum of Squares of Diameter.
I.	9	81	7·5 + 5	81·25
II.	7·2	51·64	6 + 4	52
III.	3·5	12·25	3 + 2	13
IV.	7·0	49	5 + 5	50
V.	17	289	10 + 10 + 9·5	290·25
VI.	10	100	7 + 7 + 2	102
VII.	4·5	20·25	3·5 + 3	21·25
VIII.	8	64	4 + 7	65

[1] Todd and Bowman's Physiological Anatomy, &c., Pt. iv. p. 365, Lond. 1852, or Amer. edit., Philad., 1853.

[2] Müller's Archiv., 1844, Heft i.

[3] Op. cit., p. 456.

[4] Carpenter, Op. cit., p. 266; Todd and Bowman, Op. cit., Pt. iv. p. 361, Lond., 1852, or Amer. edit., Philad., 1853; and Funke's Wagner's Lehrbuch der speciellen Physiologie, s. 85, Leipzig, 1854.

[5] London Medical Gazette, Dec. 7, 1839.

It will be observed, that the sum of the squares of the diameters of the branches is in every case slightly more than the square of the diameter of the trunk. The discrepancy was found to be somewhat greater in subsequent experiments made by Mr. Paget.[1] The following table gives the ratio of the area of each arterial trunk to the joint area of its branches, as observed by him:—

	Trunk.		Branches.
Arch of the aorta	1	:	1·055
Innominata	1	:	1·147
Common carotid	1	:	1·013
External do.	1	:	1·19
Subclavian	1	:	1·055
Abdominal aorta to the last lumbar arteries	1	:	1·183
——— just before dividing	1	:	·893
Common iliac	1	:	·982
External iliac	1	:	1·15

Analogous experiments by actual admeasurement, made by Mr. Erskine Hazard,[2] of Philadelphia, lead to a similar conclusion. In many of them, however, the area of the trunks was found to be greater than that of the branches near them. It would appear, that where the aorta divides into the common iliacs, or at the division next lower down, the stream is always contracted; the effect of which must necessarily be to accelerate the circulation not only in the iliacs themselves, but in the arteries given off from the trunk above them,—as the mesenteric and the renal.

From what has been said regarding the curvatures and angles of vessels, it will be understood, that the blood must proceed to different organs with different velocities. The renal artery is extremely short, straight, and large, and must transmit the blood very differently to the kidney, from what the tortuous carotid does to the brain; or the spermatic artery to the testicle. A different impulse must, consequently, be made on the corresponding organs by these different vessels. A great portion, however, of the impulse of the heart must fail to reach the kidney, short as the renal artery is, owing to its passing off from the aorta at a right angle; and, hence, the impulse of the blood on that organ may not be as great as might be imagined at first.

The tortuosity of the carotid arteries is such as to greatly destroy the impetus of the blood; so that but trifling hemorrhage takes place when the brain is sliced away on a living animal, although it is presumed, that one-eighth of the whole quantity of blood is sent to the encephalon. Dr. Rush supposed, that the use of the thyroid body is to break the afflux of blood to the brain; for which its situation between the heart and head appeared to him to adapt it; and he adduced, as farther arguments,—*first*, the number of arteries it receives, although effecting no secretion; *secondly*, the effect on the brain, which he conceived to be caused by disease, and extirpation, of the thyroid; the operation having actually occasioned, in his opinion, in one case, inflammation of the brain, rapidly terminating fatally; and, *thirdly*, the fact that goïtre is often accompanied by idiotism. The opinion, how-

[1] London Medical Gazette, July 8, 1842.

[2] Horner, Special Anatomy and Histology, 8th edit., ii. 167, Philad., 1851.

ever, is so entirely conjectural, and some of the *facts*, on which it rests, so questionable, that it does not demand serious examination.

This leads us to remark, that the thyroid body as well as other organs, with whose precise functions we are not well acquainted,—as the thymus, spleen, and supra-renal capsules,—have been conceived to serve as diverticula or temporary reservoirs to the blood, when, owing to special circumstances, that fluid cannot circulate properly in other parts of the frame. M. Lieutaud having observed, that the spleen is always larger when the stomach is empty than when full, considered that the blood, when digestion is not going on, reflows into the spleen, and that thus this organ becomes a diverticulum to the stomach. The opinion has been indulged by many, with more or less modification.

Dr. Rush's view was more comprehensive. He regarded the organ as a diverticulum, not simply to the stomach, but to the whole system, when the circulation is greatly excited, as in passion, or in violent muscular efforts, at which times there is danger of sanguineous congestion in different organs; and in support of this view, he invoked its spongy nature; the frequency of its distension; the large quantity of blood distributed to it; its vicinity to the centre of the circulation; and the sensation referred to it, in running, laughing, &c. M. Broussais[1] has still farther extended the notion of diverticula. He affirms, that they always exist in the vicinity of organs, whose functions are manifestly intermittent. In the fœtus, the blood does not circulate through the lungs as when respiration has been established: hence, diverticula are necessary: these are the thymus and thyroid glands. The kidneys do not act in utero; hence the use of the supra-renal capsules as diverticula. At birth, these organs are either wholly obliterated, if the organs to which they previously served as diverticula have continuous functions; or they are partly obliterated, if the functions be intermittent. Thus, the spleen continues as a diverticulum to the stomach, because its functions are intermittent through life; and the thymus disappears when respiration is established: the liver and the portal system he regards as a reservoir for the reception of blood in cases of impediment to the circulation in different parts of the body.

These notions are entirely hypothetical. We shall see, hereafter, that our ignorance of the offices of the spleen, thymus, &c., is great; and we have already shown, that much more probable uses can be assigned to the portal system. The insufficiency of M. Broussais's doctrine of diverticula is strikingly evidenced by the fact, that whilst the thymus gland disappears gradually in the progress of age, the thyroid remains, as well as the supra-renal capsules.[2]

The nature of the circulation in the brain, as well as the advantages of the tortuous arrangement of the carotids, which convey a great portion of the blood to it, has been referred to before.[3] From the mode in which its vessels—arterial and venous—are distributed to it, a uniform supply of blood is secured; and it has been presumed, that this uniformity exists to such a degree, that no augmented quantity of blood

[1] Commentaires des Propositions de Pathologie, &c., Paris, 1829; or translation, p. 214, Philad., 1832.

[2] Adelon, Physiologie de l'Homme, tom. iii. 328, 2de édit., Paris, 1829.

[3] Vol. i. p. 107.

can exist in it so as to exert undue pressure on the cerebral neurine. Resting chiefly on the recorded results of certain experiments by Dr. Kellie,[1] of Leith, many modern physiologists and therapeutists have maintained, that the quantity of blood in the cranium never varies; and that the brain is incompressible. Under this notion, Dr. Clutterbuck[2] affirmed, that no additional quantity of blood can be admitted into the vessels of the brain, the cavity of the skull being already filled by its contents. "A plethoric state or overfulness of the cerebral vessels altogether, though often talked of, can have no real existence; nor on the other hand can the quantity of blood within the vessels of the brain be diminished; no abstraction of blood, therefore, whether it be from the arm, or other part of the general system, or from the jugular veins (and still less from the temporal arteries), can have any effect on the bloodvessels of the brain, so as to lessen the absolute quantity of blood contained in them." Similar views were maintained by Monro Secundus,[3] Dr. Abercrombie,[4]—and it is affirmed by Dr. J. Hughes Bennett to be still the doctrine of "the Edinburgh school,"[5]—and they seemed to be supported by the experiments of Dr. Kellie, who inferred that, "in animals bled to death, whilst all the other organs of the body are nearly emptied of blood, the vessels of the brain contain the usual quantity; but that if, previous to bleeding an animal, a hole be made in its cranium, and the brain be thus exposed, equally with other organs, to atmospheric pressure, its vessels, like those of other parts of the body, will be emptied as the animal bleeds to death." It was important to establish the truth or inaccuracy of these views—influencing, as they were calculated to do, and have done, in so essential a manner, the therapeutics of encephalic affections; and this has been conclusively accomplished by Dr. Burrows.[6] The experiments of Dr. Kellie were repeated by him, but with *opposite* results; and he concludes, that it is not a fallacy, as some suppose, that bleeding diminishes the actual quantity of blood in the cerebral vessels;—that by it we not only diminish the momentum of the blood in the cerebral arteries and the quantity supplied to the brain in a given time, but actually diminish the amount of blood in these vessels. "Whether,"—he remarks—"the vacated place is replaced by serum or resiliency of the cerebral substance under diminished pressure, is a question into which I will not enter."

Dr. Burrows farther investigated, whether position can affect the quantity of blood in the vessels of the encephalon,—the opinion of Dr. Kellie from the results of his experiments having been in the negative. Two full grown rabbits were killed by hydrocyanic acid, and whilst their hearts still pulsated, one was suspended by the ears; the other by the hind legs. In this manner, they were left for twenty-four hours; and before they were taken down for examination, a tight ligature was placed around the throat of each, to prevent, as effectually as possible,

[1] Medico-Chirurgical Transactions of Edinburgh, i. 2.

[2] Art. Apoplexy, Cyclopædia of Practical Medicine, American edit., by the author, Philad., 1844.

[3] Observations on the Structure and Functions of the Nervous System, Edinb., 1783.

[4] Pathological and Practical Researches on Diseases of the Brain and the Spinal Cord, Edinb., 1836, or Amer. edit., Philad.

[5] Lectures on Clinical Medicine, p. 143.

[6] On Disorders of the Cerebral Circulation, Amer. edit., Philad., 1848.

any farther flow of blood to or from the head, after they were removed from their respective positions. The contrast in the appearance of the two animals was striking. The one presented a most complete state of anæmia of the internal as well as the external parts of the cranium; the other a most intense hyperæmia or congestion of the same parts; and these opposite conditions induced solely by posture, and the gravitation of the blood. Like results were obtained experimentally under the direction of Professor Donders. A portion of the skull of a rabbit was removed, the corresponding piece of the dura mater cut out, an accurately fitting portion of a watch-glass let into the opening, and the junction made air tight with gum. When by compressing the nose and mouth respiration was interrupted, within ten seconds the increased redness of the pia mater could be seen with the naked eye. This condition was made still more evident by the microscope; and some minutes always elapsed before the hyperæmia again diminished. A dependent position of the head also increased the hyperæmia; whilst rapid abstraction of blood very distinctly diminished the diameter of the vessels.[1]

The *erectile tissues* offer a variety in the circulation, which requires some comment. Examples of these occur in the corpora cavernosa of the penis and clitoris; and in the nipple. They appear, according to Gerber,[2] to consist of a plexus or rete of varicose veins enclosed in a fibrous envelope, with relatively minute interspaces, which are occupied and traversed in all directions by arteries, nerves, contractile fibres, and by elastic, fibrous and areolar tissue. The fibrous envelope, and trabeculæ, according to Kölliker,[3] contain a considerable amount of unstriped muscular fibre.

Of the particular arrangement of vessels in the corpora cavernosa of the generative organs mention will be made hereafter: the mode of termination of the arteries in the erectile tissues has not been sufficiently studied, nor are views uniform in regard to their mode of action; some being of opinion, that they afford examples of vital expansibility; but as before remarked (page 420), excitation is first induced in the nerves of the part—generally through the influence of the brain—and the turgescence of vessels is a consequence. Kölliker maintains, that the office of the muscular fibres, which pass in every direction amongst the dilated veins is to keep them compressed in the intervals of erection; and that the excitant influence to erection, which is exerted on the nervous system, either directly or through the influence of the brain, instead of causing contraction produces relaxation of the fibres, so as to admit of free distension of the cavernous vessels. It is not easy to see, however, how the nerve power sent to a muscle can cause it to become relaxed.

The arrangement of the portal system of the liver is also peculiar, and has been given already (p. 354).

[1] Cited in Brit. and For. Med.-Chir. Rev., April, 1855, p. 352.

[2] Elements of General Anatomy, by Gulliver, p. 298, Lond., 1842.

[3] Mikroskopische Anatomie, 2ter Bd. S. 414, Leipz., 1854; or Sydenham Society's edition of his Manual of Human Histology, or Amer. edit. of the same by Dr. Da Costa, p. 637, Philad., 1854.

g. *The Pulse.*

We have had occasion, more than once, to refer to the subject of the pulse, or to the beat felt by the finger when applied over any of the larger arteries. Opinions have varied essentially regarding its cause. Whilst most physiologists have believed it to be owing to distension of the arteries, caused by each contraction of the left ventricle; some have admitted a systole and diastole of the vessel itself; others, as Bichat and Weitbrecht,[1] have thought that it is owing to the locomotion of the artery; others, that the impulse of the heart's contraction is transmitted through the fluid blood, as through a solid body; and others, as Dr. Young[2] and Dr. Parry,[3] that it is owing to the sudden rush forward of the blood in the artery without distension.

Bichat was one of the first, who was disposed to doubt, whether the dilatation of the artery, which was almost universally admitted, really existed; or if it did, whether it was sufficient to explain the phenomenon; and, since his time, numerous experiments have been made by Dr. Parry, the result of which satisfied him, that not the smallest dilatation can be detected in the larger arteries, when they are laid bare during life; nor does he believe, that there is such a degree of locomotion of the vessel as can account for the effect produced upon the finger. He ascribes the pulse to "impulse of distension from the systole of the left ventricle, given by the blood, as it passes through any part of an artery contracted within its natural diameter." Dr. Bostock[4] appears to coincide with Dr. Parry, if we understand him rightly, or at all. "According to this doctrine," he remarks, "we must regard the artery as an elastic and distensible tube, which is at all times filled, although with the contained fluid not in an equally condensed state, and that the effect produced upon the finger depends upon the amount of this condensation, or upon the pressure which it exercises upon the vessel, as determined by the degree in which it is capable of being compressed. Where there is no resistance to the flow of the blood along the arteries, there is no variation, it is conceived, in their diameter, and it is only the pressure of the finger or some other substance against the side of an artery that produces its pulse."

Most of the theories of the pulse take the contractility of the artery too little into account. In pathology, where we have an opportunity for observing the pulse in various phases, we meet with sensations, communicated to the finger, which it is difficult to explain upon any theory, except that of the compound action of the heart and arteries. The impulse is obviously that of the heart, and although the fact of distension escaped the observation of Bichat, Parry, Weitbrecht, Lamure, Döllinger, Rudolphi,[5] Jäger,[6] and others, we ought not to con-

[1] Comment. Acad. Imper. Scient. Petropol. ad An. 1734 and 1735, Petrop., 1740.

[2] Croonian Lectures, in Philos. Transact. for 1809, part i.

[3] An Experimental Inquiry into the Nature, Causes, and Varieties of the Arterial Pulse, by Caleb Hillier Parry, London, 1816; also, Additional Experiments on the Arteries of Warm-blooded Animals, &c., by Charles Henry Parry, M. D., &c., London, 1819.

[4] Physiology, 3d edit., p. 246, Lond., 1836.

[5] Grundriss der Physiologie, 2ter Band. 2te Abtheil., s. 301, Berlin, 1828.

[6] Tractatus Anatomico-physiologicus de Arteriarum Pulsu., Vireeb., 1830.

clude, that it does not occur. It is, indeed, difficult for us to believe, that such an impulse can be communicated to a fluid filling an elastic vessel without pulsatory distension supervening. In opposition, too, to the negative observations of Bichat and Parry, we have the positive averment of Dr. Hastings, and of Poiseuille,[1] Oesterreicher, Ségalas, and Wedemeyer, that the alternate contraction and dilatation of the larger arteries were clearly seen.[2] M. Flourens encircled a large artery with a thin elastic metallic ring cleft at one point. At the moment of pulsation the cleft part became perceptibly widened.[3]

The pulsations of the different arteries are pretty nearly synchronous with that of the left ventricle. Those of the vessels near the heart may be regarded as almost wholly so; but an appreciable interval exists in the pulsations of the more remote.

We have remarked, that the arterial system is manifestly more or less affected by the nerves distributed to it; that it may be stimulated by irritants, applied to the great nervous centres, or to the nerves passing to it; and this is, doubtless, the cause of many of the modifications of arterial tension, noticed in disease. Inflammation cannot affect a part of the system, for any length of time, without both heart and arteries participating, and affording unequivocal evidence of it. This, however, is a subject that belongs more especially to pathology.

The ordinary number of pulsations, per minute, in the healthy adult male, is from seventy to seventy-five; but this varies greatly according to temperament, habit of life, position,—whether lying, sitting, or standing, &c. Dr. Guy,[4] from numerous observations, found the pulse, in healthy males, of the mean age of 27 years, in a state of rest, 79 when standing; 70, sitting, and 67, lying; the difference between standing and sitting being 9 beats; between sitting and lying, 3 beats; and between standing and lying, 12 beats. When all exceptions to the general rule were excluded, the numbers were;—standing, 81; sitting, 71; lying, 66;—the difference between standing and sitting being 10 beats; between sitting and lying, 5 beats; and between standing and lying, 15 beats. The effect, produced upon the pulse by change of posture, Dr. Guy ascribes to muscular contraction, whether employed to change the position of the body, or to maintain it in the same position. In children, the difference between the pulse in the sitting and lying posture is often very marked. In a boy, six years of age, observed by the author, it amounted to fifteen beats; and Dr. Evanson[5] states, that he has often found the pulse—which at night (during sleep) was 80, full and steady—up to 100 or even 120 during the day, small and hurried,—and this in children six or seven years of age, and in perfect health.

In some individuals in health, the number of beats is singularly few.

[1] Répertoire générale d'Anatomie, &c., par Breschet, 1829, tom. vi. and vii., and Magendie's Journal de Physiol., viii. and ix.

[2] For a mode of estimating the arterial distension, see Poiseuille, in Magendie's Journal de Physiologie, ix. 44, and Jules Herison's description of an instrument—*Sphygmometer*—which makes the action of the arteries apparent to the eye.

[3] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 98, Philad., 1853.

[4] Guy's Hospital Reports, No. vi., April, 1838, p. 92.

[5] Practical Treatise on the Management and Diseases of Children, by Messrs. Evanson and Maunsell: Amer. edit., by Dr. Condie, p. 19, Philad., 1843.

The pulse of a person known to the author was on the average thirty-six per minute; and Lizzari[1] affirms, that he knew a person in whom it was not more than ten. It is not improbable, however, that in these cases, obscure beats may have taken place intermediately, and yet not have been detected. In a case of pericarditis, in which the author felt great interest, the pulse exhibited a decided intermission every few beats, yet the heart beat its due number of times; the intermission of the pulse at the wrist consisting in the loss of one of the beats of the heart. It was not improbable but that in this case the contractility of the aorta was unusually developed by the inflammatory condition of the heart; and that the flow of blood from the ventricle was thus occasionally spasmodically diminished or entirely impeded. On the other hand, the natural pulse is, at times, far above the average,—100 and upwards in the minute. It is affirmed that the pulse of Sir William Congreve[2]—the inventor of the well-known Congreve rockets—when he was in apparently good health never fell below one hundred and twenty-eight beats per minute. The quickest pulse, which Dr. Elliotson[3] ever felt, was 208, counted easily, he says, at the heart; though not at the wrist.

The pulse of the adult female is usually from ten to fourteen beats in a minute quicker than that of the male. In infancy, it is generally irregular, intermitting, and always rapid, and it gradually becomes slower in the progress of age. It is, of course, impossible to arrive at any accurate estimate of its comparative frequency at different periods of life, but the following average by Heberden,[4] Sömmering, and Müller,[5] have generally been received. They are inaccurate, however, in regard to old age, more especially.

Ages.	Number of beats per minute, according to		
	Heberden.	Sömmering.	Müller.
In the embryo,	—	—	150
At birth,	130 to 140	Do.	Do.
One month,	120	—	—
One year,	120 to 108	120	115 to 130
Two years,	108 to 90	110	100 to 115
Three years,	90 to 80	90	90 to 100
Seven years,	72	—	85 to 90
Twelve years,	70	—	—
Puberty,	—	80	80 to 85
Adult,	—	70	70 to 75
Old age,	—	60	50 to 65

A nearer approximation is given by Dr. Guy in the following table:—

[1] Raccolta D'Opusculi Scientific., p. 265; and Good's Study of Medicine, Physiological Proem to class iii. Hæmatica. See Cases of Slowness of Pulse, by Mr. Mayo, Lond. Med. Gaz., May 5, 1838, p. 232.

[2] Adventures and Recollections of Colonel Landmann, late of the Corps of Royal Engineers, i. 12, London, 1852.

[3] Human Physiology, p. 215, London, 1840.

[4] Med. Transact., ii. 21.

[5] Handbuch der Physiologie, Baly's translation, p. 171, London, 1838.

Age.	Maximum.	Minimum.	Mean.	Range.
2 to 5	128	80	105	48
5 to 10	124	72	93	52
10 to 15	120	68	88	52
15 to 20	108	56	77	52
20 to 25	124	56	78	68
25 to 30	100	53	74	47
30 to 35	94	58	73	36
35 to 40	100	56	73	44
40 to 45	104	50	75	54
45 to 50	100	49	71	51
50 to 55	88	55	74	33
55 to 60	108	48	74	60
60 to 65	100	54	72	46
65 to 70	96	52	75	44
70 to 75	104	54	74	50
75 to 80	94	50	72	44
80 and upwards, . . .	98	63	79	35

Dr. Guy[1] lays down the following as a near approximation to the average numbers at the several leading periods of life. It must be borne in mind, that, as in all similar cases, such averages can never apply to special examples.

At birth, ...	140	Adult age, ...	75
In infancy, ...	120	Old age, ...	70
Childhood, ...	100	Decrepitude, ...	75—80
Youth, ...	90		

Researches by MM. Hourmann and Dechambre,[2] do not accord with the estimates in respect to the smaller number of pulsations in the aged. MM. Leuret and Mitivié had suspected an error in this matter from an examination of 71 of the aged inmates of the Bicêtre and La Salpêtrière. MM. Hourmann and Dechambre examined 255 women between the ages of 60 and 96, and found the average number of the pulse to be 82·29. M. Rochoux,[3] however, still believes—from the results of his own observations as well as those of others—that, as a general rule, the frequency of the pulse diminishes in the progress of age. The attention of Dr. Pennock,[4] of Philadelphia, has more recently been directed to the subject; and the author has great confidence in the authenticity of results recorded by him. In 170 males, and 203 females, of the average age of about 67, the average frequency of the pulse was 75. The difference between the pulse of the male and female continues to be well marked in advanced life. MM. Leuret and Mitivié found the average frequency in 27 aged men, 73; and in 34 aged women, 79. The average obtained by Dr. Pennock was 72 for the former; 78 for the latter.

Dr. Gorham[5] assigns 130 as the mean number of the pulse from five months to two years old; and 107·63 from two to four years, whence the number continues almost the same up to the tenth year.

[1] Art. Pulse, Cyclop. of Anat. and Physiol., Pt. xxxi. p. 183, Lond., May, 1848.
[2] Archiv. Générales de Méd. pour 1835.
[3] Art. Pulse, in Dict. de Méd., 2de édit., xxv. 619, Paris, 1842.
[4] Amer. Journ. of the Medical Sciences, July, 1847, p. 68.
[5] Lond. Med. Gaz., Nov. 25, 1837.

His estimates, however, are much higher than those of M. Valleix.[1] M. Trousseau,[2] from repeated observations, infers, that but little stress ought to be laid on the pulse in the diagnosis of disease in infants. He found, that during the first two weeks, it may vary from 78 to 150; during the second fortnight, from 120 to 164; from one to two months, from 96 to 132; two to six months, 100 to 162; six to twelve months, 100 to 160; and from twelve to twenty-one months, 96 to 140. From the observations of MM. Billard, Valleix, and others, it would seem, that the pulse of the fœtus at the moment it is expelled from the uterus often falls to 83 in the minute, and, in some minutes afterwards, rises to 160. In the course of the first day, it falls again to 127, and continues to diminish during the first ten days, the average being then from 87 to 90. These are, however, only averages: the variations are very great. Sex appeared to have some influence. In infants, from eight days to six months old, the average number of pulsations for boys was 131; for girls, 134; from six to twenty-one months, the average for boys was 113; for girls, 126. The state of sleeping or waking had a greater influence. In infants from fifteen days to six months old, the average of the pulse was 140 during waking; 121 during sleep. He has known it rise from 112 to 160 and 180, when the child cried or struggled. On the whole, M. Trousseau concludes, that the pulse of children at the breast varies from 100 to 150. After the first two months, it is a little more frequent in females than in males; and is about 20 higher in the waking than in the sleeping state.

Strange to say, it may be wholly absent, without the health seeming to be interfered with. A case of the kind is referred to by Prof. S. Jackson,[3] as having occurred in the mother of a physician of Philadelphia. The pulse disappeared during an attack of acute rheumatism, and could never again be observed. Yet she was active in body and mind, and possessed unusual health. In no part of the body could a pulse be detected. Dr. Jackson attended her during a part of her last illness—inflammation of the intestines; no pulse existed. She died whilst he was absent from the city, and no examination of the body was made.

Between the number of pulsations and respirations there would not appear to be any fixed relation. In many persons the ratio in health is 4 to 1,[4] but in disease it varies greatly.[5] Dr. Elliotson[6] alludes to a case of nervous disease in a female at the time in no danger whose respiration was 106, and pulse 104.

[1] Mémoires de la Société Médicale d'Observation de Paris, tom. ii., Paris, 1844.

[2] Journ. des Connaiss. Méd.-Chir., Juillet & Août, 1841; cited in Amer. Journ. of the Med. Sciences, Oct., 1841, p. 458, and Jan., 1842, p. 199.

[3] The Principles of Medicine, founded on the Structure and Functions of the Animal Organism, p. 492, Philad., 1832. A case of complete disappearance of the beating of the heart is in Gazette Médicale, 21 Nov., 1836; and analogous cases are given in Parry on the Pulse, Bath, 1816, and in Medico-Chirurg. Review, xix. 285, and April, 1836.

[4] Quetelet, Sur L'Homme, p. 87; also, Guy, Pennock, &c., in Art. Pulse, op. cit., and Dr. John Reid, art. Respiration, ibid., pt. xxxii. p. 338, Lond., 1848.

[5] P. A. Jochmann, Beobachtungen über die Körperwärme in Chronischen Fieberhaften Krankheiten, s. 82, Berlin, 1853.

[6] Human Physiology, p. 215, Lond., 1835. See, also, Dr. Ch. Hooker, of New Haven, Conn., in Boston Medical and Surgical Journal, for May 16, 23, &c., 1838.

Dr. Knox[1] has made some observations on the pulsations of the heart, and on its diurnal revolution and excitability, from which he infers: 1. The velocity of the heart's action is in a direct ratio with the age of the individual,—being quickest in young persons, slowest in the aged. There may be exceptions to this, but they do not affect the general law. 2. There are no data to determine the question of an average pulse for all ages. 3. There is a morning acceleration and an evening retardation in the number of the pulsations independently of any stimulation by food, &c. 4. The excitability of the heart undergoes a daily revolution;—that is, food and exercise affect its action most in the morning and during the forenoon; less in the afternoon, and least of all in the evening. Hence it might be inferred, that the pernicious use of spirituous liquors must be greatly aggravated in those who drink before dinner. 5. Sleep does not farther affect the heart's action than through the cessation of all voluntary motion, and a recumbent position. 6. In weak persons, muscular action excites that of the heart more powerfully than in the strong and healthy; but this does not apply to other stimulants,—wine and spirituous liquors, for example. 7. The effect of the position of the body in increasing or diminishing the number of pulsations is solely attributable to the muscular exertion required to maintain the body in the sitting or erect posture; the debility may be measured by altering the position of the person from a recumbent to a sitting or erect one. 8. The most powerful stimulant to the heart's action is muscular exertion. The febrile pulse never equals this.[2]

h. *Uses of the Circulation.*

The chief uses of the circulation are,—to transmit to the lungs the products of absorption, in order that they may be converted into arterial blood; and to convey to the organs such arterial blood, which is not only necessary for their vitality, but is the fluid by which the different processes of nutrition, calorification, and secretion are effected. The vessels are the mere carriers of pabulum to the tissues; the cells of which obtain from the blood the materials that are necessary for building up each tissue. It is therefore outside of the vessel, that every formative act is accomplished. Mr. Paget[3] properly animadverts on the error and confusion, which result from speaking of the "action of vessels," as if the vessels really made and unmade the parts. "We have no knowledge"—he adds—"of the vessels as anything but carriers of the materials of nutrition to and fro. These materials may, indeed, undergo some change as they pass through the vessels' walls; but that change is not an assuming of definite shape; the vessels only convey and emit the 'raw material;' it is made up in the parts, and in each after its proper fashion. The real process of formation of tissues is altogether extra-vascular, even, sometimes, very far extra-vascular; and its tissue depends in all cases chiefly, and in some

[1] Edinburgh Medical and Surgical Journal, April, 1837.

[2] The article on the Pulse, by Dr. Guy, in Cyclop. of Anat. and Physiology, is an excellent *resumé* of the whole subject. See also Bérard, Cours de Physiologie, 31e livraison, p. 101, Paris, 1855.

[3] Lectures on Surgical Pathology, Amer. edit., p. 40, Philad., 1854.

entirely, on the affinities (if we may so call them) between the part to be nourished and the nutritive fluid."

It may be remarked in conclusion, that the agency of the blood, as the cause of health or disease, has had greater importance assigned to it than it merits; and that although the blood may be the medium, by which the source of disease is conveyed to other organs, we cannot look to it as the seat of those taints that are commonly referred to it. "Upon the whole," says Dr. Good,[1] "we cannot but regard the blood as, in many respects, the most important fluid of the animal machine: from it all the solids are derived and nourished, and all the other fluids are secreted; and it is hence the basis or common pabulum of every part. And as it is the source of general health, so is it also of general disease. In inflammation, it takes a considerable share, and evinces a peculiar appearance. The miasms of fevers and exanthems are harmless to every part of the system, and only become mischievous when they reach the blood; and emetic tartar, when introduced into the jugular vein, will vomit in one or two minutes, although it might require perhaps half an hour if thrown into the stomach, and in fact it does not vomit till it has reached the circulation. And the same is true of opium, jalap, and most of the poisons, animal, mineral, and vegetable. If imperfectly elaborated, or with a disproportion of some of its constituent principles to the rest, the whole system partakes of the evil, and a dysthesis or morbid habit is the certain consequence; whence tabes, atrophy, scurvy, and various species of gangrene. And if it becomes once impregnated with a peculiar taint, it is wonderful to remark the tenacity with which it retains it, though often in a state of dormancy and inactivity for years, or even entire generations. For as every germ and fibre of every other part is formed and regenerated from the blood, there is no other part of the system that we can so well look to as the seat of such taints, or the predisposing cause of the disorders I am now alluding to; often corporeal, as gout, struma, phthisis: sometimes mental, as madness; and occasionally both, as cretinism."

This picture is largely overdrawn. Setting aside the erroneous pathological notions that assign to the blood what properly belongs to cell life in the system of nutrition, how can we suppose a taint to continue for years, or even entire generations, in a fluid which is perpetually undergoing mutation; and, at any distant interval, cannot be presumed to have one of its quondam particles remaining? Were all hereditary diseases derived from the mother, we could better comprehend this doctrine of taints; inasmuch as, during the whole of fœtal existence, she transmits the pabulum for the support of her offspring. The child is, however, equally liable to receive the taint from the father, who supplies no pabulum, but merely a secretion from the blood at a fecundating copulation, and from that moment can exert no influence on the character of the progeny. The impulse to this or that organization or conformation must be given from the moment of union of the particles, furnished by each parent at a fecundating intercourse; and it is probable, that no material influence is exerted sub-

[1] Op. cit.

sequently even by the mother, except through the pabulum she furnishes. The embryo accomplishes its own construction, as independently of the parents as the chick *in ovo*.

i. *Transfusion and Infusion.*

The operation of Transfusion,—as well as of Infusion of medicinal agents,—was referred to in an early part of this chapter, to prove the course of the circulation to be from the arteries into the veins. Both these operations were suggested by the discovery of Harvey. The former, more especially, was looked upon as a means of curing all diseases, and of renovating the aged *ad libitum*. The cause of every disease and decay was presumed to reside in the blood, and, consequently, all that was necessary was to remove the faulty fluid, and substitute pure blood obtained from a healthy animal in its place.

As a therapeutical agency, the history of this operation does not belong to physiology. The detail of the fluctuation of opinions regarding it, and its total disuse, are given at some length in the Histories of Medicine, to which we must refer the reader.[1] It appears to have been first performed on man in France by Denis and Emmerets in 1666; and in the following year it was practised in England by Drs. Lower and King.[2] Before this, however, many experiments had been made on animals. In his "Diary" under the date of the 14th of November, 1666, Pepys[3] has the following entry:—"Dr. Croone told me, that at the meeting of Gresham College to-night, which, it seems, they now have every Wednesday again, there was a pretty experiment of the blood of one dog let out, till he died, into the body of another on one side, while all his own run out on the other side. The first died upon the place, and the other very well, and likely to do well. This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an Archbishop, and such like; but, as Dr. Croone says, may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body."

There are some interesting physiological facts, connected with transfusion, that cannot be passed over. MM. Prévost and Dumas found that the vivifying power of the blood does not reside so much in the serum as in the red particles. An animal bled to syncope was not revived by the injection of water or of pure serum at a proper temperature; but if blood of one of the same species was used, the animal seemed to acquire fresh life at every stroke of the piston, and was at length restored.

The operation was revived by Dr. Blundell,[4] and by MM. Prévost and Dumas;[5] the first of whom employed it with safety, and he thinks with happy effects, in exhausting uterine hemorrhage. All these gen-

[1] K. Sprengel, Histoire de Médecine, par Jourdan, iv. 120, Paris, 1815.

[2] J. P. Kay, art. Transfusion, Cyclopædia of Practical Medicine, Amer. edit., by the author, iv., 468, Philad., 1845; and The Physiology, &c. of Asphyxia, p. 254, Lond., 1834.

[3] Diary and Correspondence of Samuel Pepys, F. R. S., by Lord Braybrooke, 3d edit., iii. 336, London, 1848.

[4] Médico-Chirurgical Transactions, ix. 56; and x. 296; and Researches, physiological and pathological, p. 63, London, 1825.

[5] Bibliothèque Universelle, xvii. 215.

tlemen remark, that it can only be adopted with perfect safety in animals of like kinds, or in those the corpuscles of whose blood are of similar configuration. MM. Prévost and Dumas, Dieffenbach,[1] and Bischoff,[2] agree as to the deadly influence of the blood of the mammalia when injected into the veins of birds. This influence, according to Müller,[3] is in some way connected with the fibrin of the blood, as when blood deprived of fibrin was injected into the vessels, the animal appeared to suffer no inconvenience.

The introduction of the practice of *infusing* medicinal agents into the blood was coëval with that of transfusion. It appears to have been first subjected to a philosophical examination by Sir Christopher Wren, who practised it on a malefactor in 1656.[4]

It is a singular fact, that in cases of infusion, medicinal substances are found to exert their specific actions upon certain parts of the body, precisely in the same manner as if they had been received into the stomach. Tartar emetic, for example, vomits, and castor oil purges not only as certainly, but with much greater speed; for, whilst the former, as before remarked, requires to be in the stomach for fifteen or twenty minutes, before vomiting is excited, it produces its effect in one or two minutes, when thrown into the veins. Dr. E. Hale, of Boston, has published an interesting pamphlet on this subject.[5] In it he traces the history of the operation, detailing several interesting experiments upon animals; and one upon himself, which consisted in the introduction of a quantity of castor oil into the veins. In this experiment, he did not feel much inconvenience immediately after the injection; but very speedily experienced an oily taste, which continued for a length of time, and the medicine occasioned much gastric and intestinal disturbance, but did not act as a cathartic. Considerable difficulty was experienced in the introduction of the oil, to which circumstance M. Magendie[6] ascribes Dr. Hale's safety; for it is found, by experiments on animals, that viscid fluids, such as oil, are unable to pass through the pulmonary capillaries, in consequence of which the circulation is arrested, and death follows. Such, also, appears to have been the result of the experiments of Dr. Hale with powdered substances.

The injection of medicines into the veins has been largely practised at the Veterinary School of Copenhagen, and with complete success—the action of the medicine being incomparably more speedy, and the dose required much less. It is rarely employed by the physician, except in experiments on animals; but it is obvious, that it might be had recourse to with happy effects, where narcotic and other poisons have been taken, and where the mechanical means for their removal are not at hand.

[1] Die Transfusion des Blutes, Berlin, 1828.

[2] Müller's Archiv., 1835; cited in Baly's translation of J. Müller's Handbuch, u. s. w.

[3] Handbuch der Physiologie, Baly's translation, i. 141, London, 1838. See, on the different effects of transfusion of arterial and venous blood on animals, Bischoff, in Müller's Archiv., Heft iv. 1838, cited in Brit. and For. Med. Rev., April, 1839, p. 548.

[4] Chelius, System of Surgery, translated by South, Amer. edit., iii. 626, Philad., 1847.

[5] Boylston Medical Prize Dissertations for the years 1819 and 1821, p. 100, Boston, 1821.

[6] Précis, &c., ii. 430.

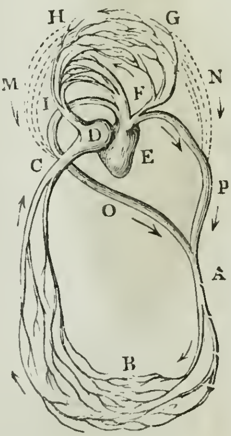
4. CIRCULATORY APPARATUS IN ANIMALS.

In concluding this subject, a brief allusion to the circulatory apparatus of other parts of the animal kingdom may be interesting and instructive.

In the *mammalia* in general, the inner structure of the heart is the same as in man; but its situation differs materially; and in some of them, as in the stag and pig, two small flat bones, called *bones of the heart*, exist, where the aorta arises from the left ventricle. In the amphibious mammalia and the cetacea, it has been supposed, that the foramen ovale in the septum between the auricles is open as in the human fœtus, to allow them to pass a considerable time under water without breathing; but the observations of Blumenbach, Cuvier, and others seem to show, that it is almost always closed. Sir Everard Home found it open in the sea otter, in two instances; but these are regarded by naturalists as exceptions to the general rule. In several of the web-footed mammalia and cetacea, as in the common otter, sea otter, and dolphin, particular vessels are always greatly enlarged and tortuous;—a structure which has been chiefly noticed in the vena cava inferior, and is supposed to serve the purpose of a diverticulum, whilst the animal is under water; or to receive a part of the returning blood, and retain it until respiration can be resumed.

In *birds*, the structure of the heart universally possesses a singular peculiarity. Instead of the right ventricle having a membranous valve, as in the left, and as in all the mammalia, it is provided with a strong, tense, and nearly triangular muscle, which aids in the propulsion of the blood from the right side of the heart into the lungs. This is presumed to be necessary, in consequence of their lungs not admitting of expansion like those of the mammalia, and of their being connected with numerous air-cells.

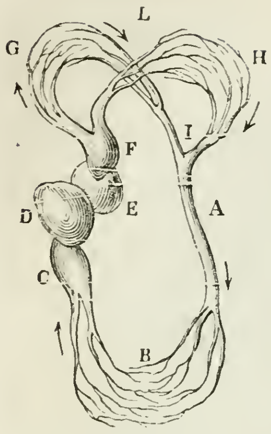
Fig. 126.



Circulation in the Frog.

The heart of *reptiles* or *amphibia* in general consists either of only one ventricle, or of two, which freely communicate, so as to constitute essentially but one. The number of auricles always corresponds with that of the ventricles. That the cavities—auricular and ventricular—are, however, single, although apparently double, is confirmed by the fact, that, in all, there is only a single artery proceeding from the heart, which serves both for the pulmonic and systemic circulations. After this vessel has left the heart, it divides into two branches, by one of which a part only of the blood is conveyed to the lungs, whilst the other proceeds to different parts of the body. These two portions are united in the heart, and after being mixed together are sent again through the great artery. In these animals, therefore, aeration is less extensive than in the higher; and we can thus understand many of their peculiarities:—how, for example, the circulation may continue, when the animal is so situate as to be incapable, for a time, of respiration; as well as the great

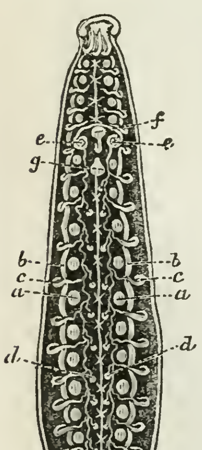
Fig. 127.



Circulation in Fishes.

resistance to ordinary deranging influences, by which they are characterized. Fig. 126 represents the circulatory apparatus of the *frog;* in which E is the ventricle and D the auricle. From the former arises the aorta F, which soon divides into two trunks. These, after sending branches to the head and neck, turn downwards (O and P), and unite in the single trunk A. This vessel sends arteries to the body and limbs, which ultimately terminate in veins, and unite to form the vena cava C. From each of the trunks into which the aorta bifurcates at its origin arise the arteries F. These are distributed to the lungs, and communicate with the pulmonary veins, which return the blood to the auricle, D, where it becomes mixed with the blood of the systemic circulation. In the *tadpole* state, the circulation is branchial, as in fishes. The heart then sends the whole of its blood to the *branchiæ* or gills, and it is returned by veins following the course of the dotted lines M and N (Fig. 126), which unite to form the descending aorta. As the lungs undergo their developement, small arterial branches arise from the aorta and are distributed to those organs; and in proportion as these arteries enlarge, the original branchial arteries diminish, until ultimately they are obliterated, and the blood flows wholly through the enlarged lateral trunks, O and P, which, by their union, form the descending aorta.

Fig. 128.



Interior of the Leech.

a, a. Respiratory cells. *b, b.* Two large arteries. *c, c.* Mucous glands. *d, d.* Glands connected with the testicles. *e, e.* Testicles. *f.* Penis. *g.* Uterus.

In *fishes*, the heart is extremely small, in proportion to the body; and its structure is simple; consisting of a single auricle and ventricle, D and E (Fig. 127). From the ventricle E an arterial trunk arises, which, in most fishes, is expanded into a kind of bulb, F, as it leaves the heart, and proceeds straight forward to the *branchiæ* or *gills*, G and H. From these, the blood passes into a large artery, A, analogous to the aorta, which proceeds along the spine, and conveys the blood to the various parts of the system; and, by the vena cava, C, the blood is returned to the auricle. This is, consequently, a case of single circulation.

Insects appear to be devoid of bloodvessels. Cuvier examined all the organs in them, which, in red-blooded animals, are most vascular, without discovering the least appearance of a bloodvessel, although extremely minute ramifications of the trachea were obvious in every part. Insects, however, both in their perfect and larve state, have a membranous tube running along the back, in which alternate dilatations and contractions are perceptible, and which has been considered as their heart; but it is closed at both ends, and no vessels can be perceived originating from it. To this the innumerable ramifications of the trachea convey the air, and thus, as Cuvier has remarked, "le sang ne pouvant aller chercher l'air, c'est l'air qui va chercher le sang" ("the blood not being able to go in search of the air—the air seeks the blood"). Carus, however, discovered a continuous circulation through arteries and veins in a few of the perfect insects, and especially in some larves. Lastly: in many genera of the class *vermes*, particularly amongst molluscous animals, there is a manifest heart, which is sometimes of a singular structure. Some of the bivalves—it is affirmed—have as many as four auricles; whilst many animals,—as the leech and *Lumbricus marinus*,—have no heart; but circulating vessels exist, in which contraction and dilatation are perceptible.

The marginal figure (Fig. 128), of the interior of a leech, given by Sir Everard Home, exhibits the mode of circulation and respiration in that animal. There is no heart, but a large vessel exists on each side. The water is received, through openings in the belly, into the cells or respiratory organs, and passes out through the same.

CHAPTER V.

NUTRITION.

THE investigation of the phenomena of the circulation has exhibited the mode in which arterial blood is distributed over the body in minute vessels, not appreciable by the naked eye, and often not even with the microscope, and so numerous, that it is impossible for the finest-pointed instrument to be forced through the skin without penetrating one, and perhaps several. It has been seen, likewise, that in the capillary system of vessels, this arterial blood is changed into venous; and it was observed, that in the same system, parts are deposited or separated from the blood, and certain phenomena occur, into the nature of which we have now to inquire; beginning with those of *nutrition*, which comprise the incessant changes that are taking place in the body, both of absorption and deposition for the decomposition and renovation of each organ. Nutrition is well defined by M. Adelon[1] as the action, by which every part of the body, on the one hand, appropriates or assimilates to itself a portion of the blood distributed to it; and, on the other, yields to the absorbing vessels a portion of the materials that previously composed it. The precise character of the apparatus, by which this important function is accomplished, we have no exact means of knowing. All admit that the old matter must be taken up by absorbents, and the new be deposited by arteries, or by vessels continuous with them. As the precise arrangement of these minute vessels is not perceptible by the eye, even when aided by powerful instruments, their arrangement has given rise to controversy. Whilst some have imagined lateral pores in the capillaries, for the transudation of nutritive deposits; others have presumed, that inconceivably small vessels are given off from the capil-

[1] Physiologie de l'Homme, tom. iii. p. 359, 2de édit., Paris, 1829.

lary system, which constitute a distinct order, and whose function is to exhale the nutritive substance,—an idea, which, as has been said elsewhere, has been revived by M. Bourgery. Hence, they have been termed *exhalants* or *nutritive exhalants;* but the anatomical and physiological student must bear in mind, that whenever the term is used by writers, they do not always pledge themselves to the existence of any distinct set of vessels, but merely mean the minute vessel, whatever may be its nature, which is the agent of nutrition, and conveys the pabulum to the different tissues.

In investigating the physiology of nutrition, two antagonistic processes demand attention; 1st. *Decomposition*, by which the tissue yields to the absorbing vessels a portion of its constituents; and 2dly. *Composition*, by which it assimilates a part of the arterial blood that enters it, and supplies the loss it had sustained by the previous act of decomposition. The former of these actions obviously belongs to the function of absorption; but its consideration was deferred, in consequence of its close application to the function we are about to investigate. It comprises what is meant by *interstitial*, *organic*, or *decomposing absorption*, and does not require many comments, after the long investigation of the general phenomena of absorption into which we entered. The conclusion then arrived at, was,—that the chyliferous and lymphatic vessels form chyle and lymph, respectively, refusing the admission of most other substances;—but that they and the veins admit every liquid which possesses the necessary tenuity; and that whilst all the absorptions,—which require the substance acted upon to be decomposed and transformed,—are effected by the chyliferous and lymphatic vessels, those that demand no alteration are chiefly accomplished through the coats of the veins by imbibition. It is easy, then, to deduce the agents to which we refer the absorption of decomposition. As it is exerted on solids, and as these cannot pass through the coats of the vessel in their solid condition, it follows that other agents than the veins must accomplish the process; and, again, as we never find in the lymphatic vessels any thing but lymph, and have every reason to believe, that an action of selection is exerted at their extremities, similar to that of the chyliferous vessels on the heterogeneous substances exposed to them, we naturally look to the lymphatics as the main, if not the sole, organs concerned in the absorption of solids.

It appears manifest that the different tissues are endowed with a vital attractive and elective force, which they exert upon the blood;—that each tissue attracts only those materials of which it is itself composed; and thus, that the whole function of nutrition is an affair of elective affinity; yet this cannot be the force that presides over the original formation of the tissues in the embryo. An attraction cannot be exerted by parts not yet in existence. To account for this, it has been imagined, that a peculiar force is destined to preside over formation and nutrition, and various names have been assigned to it. By most of the ancients it was termed *facultas formatrix*, *nutrix*, *auctrix;* by Van Helmont,[1] *Blas alterativum;* and by Bacon,[2] *motus assimilationis.* It is the

[1] Opera, pars i.

[2] Novum Organum, lib. ii. aphor. 48.

facultas vegetativa of Harvey;[1] the *anima vegetativa* of Stahl;[2] the *puissance du moule intérieur* of Buffon;[3] the *vis essentialis* of C. F. Wolff;[4] and the Bildungstrieb or *nisus formativus* of Blumenbach and most German writers.[5] This force is meant, when writers speak of *germ force*, *plastic force*, *force of nutrition*, *force of formation*, and *force of vegetation.* Whatever difference there may be in the terms selected, all appear to regard it as charged with maintaining, for a certain length of time, living bodies and all their parts, in the possession of their due composition, organization, and vital properties; and of putting them in a condition, during a certain period of their existence, to produce beings of the same kind as themselves. It is obvious, however, that none of these terms elucidate the intricate phenomena of nutrition, and none express more than—that living bodies possess a *vital force*, under the action of which, formation and nutrition are accomplished.

The important—indispensable—actions that constitute nutrition occur in the tissues supplied by the intermediate or capillary system of vessels; but not in those vessels themselves. Their function—as before remarked—is to convey to the system of nutrition the pabulum from which the tissues are formed; but the formation of the tissues takes place on the outside of the vessel; and the organic cells are the immediate agents. It is not, however, the whole of the circulating fluid that constitutes such pabulum. The blood corpuscles—excepting in a single case, menstruation—are not found outside the vessels in the exercise of the healthy functions. The liquor sanguinis alone transudes, and is the material on which the nucleated cell exerts its plastic power.[6]

Under the idea that all the vessels of the capillary system are possessed of coats, it is not so easy to comprehend how either nutrition or secretion can be accomplished. Were we to adopt the opinion, before referred to, that many of the vessels of the capillary system consist of membraneless or coatless tubes, it would be more readily understood, that by the elective and attractive forces possessed by the tissues and exerted by them on the blood, materials may be obtained from that fluid as it passes through the intermediate system of vessels, which may be inservient to the nutrition of the tissues bathed by it. The mode in which the blood is distributed through the tissues may be likened to the distribution of the water of a river through a marsh, which conveys to the animal and vegetable bodies that flourish in it the materials for their nutrition. To adopt the language of an intelligent and philosophical writer,[7] "In every part of the body, in the brain, the heart, the lung, the muscle, the membrane, the bone, each tissue attracts only those constituents of which it is itself composed. Thus, the common current, rich in all the proximate constituents of the tissues, flows out to each. As the current approaches the tissue,

[1] De Generatione Animalium, Lond., 1651, p. 170.
[2] Theoria Medica Vera. Hal., 1708. [3] Histoire Naturelle, tom. ii.
[4] De Generatione, Hal., 1759.
[5] Comment. Societ. Gotting., tom. viii.; and Institutiones Physiologicæ, § 31, Gotting., 1798.
[6] Mulder, The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 597, Edinburgh and London, 1849. See, also, on this subject, Paget, Surgical Pathology, Amer. edit., p. 140, Philad., 1854.
[7] The Philosophy of Health, by Dr. Southwood Smith, vol. i. p. 405, London, 1835.

the particles appropriate to the tissue feel its attractive force, obey it, quit the stream, mingle with the substance of the tissue, become identified with it, and are changed into its own true and proper nature. Meantime, the particles which are not appropriate to that particular tissue, not being attracted by it, do not quit the current, but, passing on, are borne by other capillaries to other tissues, to which they are appropriate, and by which they are apprehended and assimilated. When it has given to the tissues the constituents with which it abounded, and received from them particles no longer useful, and which would become noxious, the blood flows into the veins, to be returned by the pulmonic heart to the lung, where, parting with the useless and noxious matter it has accumulated, and replenished with new proximate principles, it returns to the systemic heart, by which it is again sent back to the tissues."

Particles of blood are seen to quit the current and mingle with the tissues; particles are seen to quit the tissues, and mingle with the current; but all that we can see, as Dr. Smith has remarked, with the best aid we can get, does but bring us to the confines of grand operations, of which we are altogether ignorant. It is not necessary, however, for the nutrition of certain parts, that they should receive capillary vessels. There are tissues, commonly termed extra-vascular, in the substance of which neither injection nor the microscope has exhibited the existence of bloodvessels, and which would seem to derive their nourishment by imbibition from blood flowing in the vessels of adjacent tissues. To these belong the crystalline body, epidermis and epithelium, hair, nails, enamel of the teeth, &c., &c.

We have said that the main, if not the sole, agents of the absorption of solids are the lymphatics. Almost all admit, that they receive the products of the absorption of solids; but all do not admit, that the action of taking up solid parts is accomplished immediately by the absorbents. They who think, that a kind of spongy tissue or "parenchyma" exists at the radicles of the absorbent vessels, believe that this sponge possesses a vital action of absorption, when bodies, possessing the requisite constitution and consistence, are put in contact with it; but they maintain, that the solid parts are broken down by the same agents—the extreme arteries—which secreted them, and that, when reduced to the proper fluid condition, they are imbibed by the parenchyma, and conveyed into the lymphatics. But if the existence of this sponge were demonstrated, the above explanation would scarcely be admissible, for it could not be conceived to do more than imbibe; it could not break down solids, and reduce them to lymph—the only fluid which, as we have seen, is ever met with in lymphatics. Its existence is, however, altogether supposititious. Besides, the arrangement has not been invoked in favour of the chyliferous vessels, which are so analogous in their organization and functions to the lymphatics. It has not been contended, that the arteries of the intestinal canal form the chyle from the alimentary matters in the small intestine, and that the office of the chyliferous vessels is restricted to the reception of this chyle, imbibed and brought in contact with their radicles by the ideal sponge or parenchyma.

We have before shown, that there is every reason for the belief, that a vital action of selection and elaboration exists at the very origin of the chyliferous vessels; and the same may be inferred of the lymphatics. The great difficulty has been to understand how either exhaling artery or absorbing lymphatic can reduce the solid matter—of bone, for example—to the constitution and consistence requisite for entering the lymphatics; but we might conceive, that the latter as readily as the former, by virtue of its vital properties—for the operation must be admitted by all to be vital—and by means of its contained fluid, might soften the solid so as to admit of its being received into the vessel. We should still, however, have to explain the mysterious operation by which those absorbents are enabled to reduce to their elements, bone, muscle, tendon, &c., and to recompose them into the form of lymph. Dr. Bostock[1] fancifully suggests, that the first step in this series of operations is the death of the part; by which expression he means, that it is no longer under the influence of arterial action. "It therefore ceases to receive the supply of matter which is essential to the support of all vital parts, and the process of decomposition necessarily commences." The whole of his remarks on this subject are eminently gratuitous, and appear to be suggested by an extreme unwillingness to ascribe the process to any thing but physical causes. If there be, however, any one phenomenon of the animal economy, which is more manifestly referable to vital action than another, it is the function of nutrition, both as regards the absorption of parts already deposited, and the exhalation of new. We know that the blood contains most of the principles that are necessary for the nutrition of organs, and that it must contain the elements of all. Fibrin, albumen, fat, salts, &c., exist in it, and these are deposited, as the blood traverses the tissues; but why one of these should be selected by one set of vessels, and another by another set, and in what manner the elements of those, not already formed in the blood, are brought together, is unknown to us.

Blood has been designated as "liquid flesh,"—*chair coulante*,—but something more than simple transudation through vessels is necessary to form it into flesh, and to give it the compound organization of fibrin, gelatin, osmazome, &c.—in the form of muscular fibre and areolar membrane—as we observe in the muscle. Nothing, perhaps, has more clearly exhibited the want of knowledge on this subject than the following vague attempt at solving the mystery by one of the most distinguished physiologists of the age. "Some immediate principles, that enter into the composition of the organs or of the fluids, are not found in the blood,—such as gelatin, uric acid, &c. They are consequently formed at the expense of other principles, in the parenchyma of the organs, and by a chemical action, the nature of which is unknown to us, but which is not the less real, and must necessarily have the effect of developing heat and electricity."

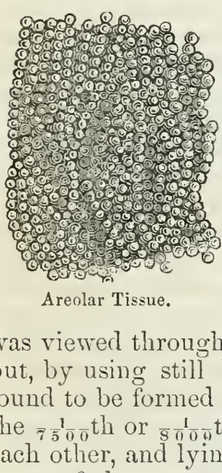
The views of recent histologists have approximated us more to a true knowledge of this mysterious action. They have not been content with endeavouring to reduce the different organized textures to primary fibres and filaments, but, by the aid of the microscope, have attempted to discover the particular arrangement and mode of forma-

[1] System of Physiology, edit. cit., p. 625.

tion of the constituent corpuscles. The discovery of that valuable instrument gave the impulse; and very soon the scientific world was presented with the results obtained by numerous observers. These observations have been, from time to time, continued until the present day. It is, however, to be regretted, that, until recently, our information, derived from this source, was not as accurate as was desirable. From different quarters, the most discordant statements were presented, exhibiting clearly, either that the narrators employed instruments of very different powers, or that they were blinded, or had the vision depraved, by preconceived theories or hypotheses.

One of the very first effects of the discovery of the microscope was the detection by Leeuenhoek,[1] of a globular structure of the primitive tissues of the body, an announcement which gave rise to much controversy, and engaged the attention particularly of Prochaska,[2] Fontana,[3] Sir Everard Home, Mr. Bauer, the brothers Wenzel,[4] M. Milne Edwards, MM. Prévost and Dumas,[5] Dutrochet, Hodgkin,[6] Raspail, and others.[7] The observations and experiments of Dr. Edwards, more especially, occasioned at the time much interesting speculation and inquiry. They may perhaps be taken as the foundation on which the believers in the globular structure of later years rested their opinions. His views were first published in 1823, in a communication, entitled "*Mémoire sur la Structure élémentaire des principaux Tissues Organiques des Animaux;*" and in a second article in the *Annales des Sciences Naturelles*, for December, 1826, entitled "*Recherches microscopiques sur la Structure intime des Tissues Organiques des Animaux.*" He examined all the principal textures of the body, the areolar tissue, membranes, tendons, muscular fibre, nervous tissue, skin, coats of the bloodvessels, &c. When the areolar tissue was viewed through a powerful lens, it seemed to consist of cylinders; but, by using still higher magnifying powers, these cylinders were found to be formed of rows of globules of the same size, that is, about the $\frac{1}{7500}$th or $\frac{1}{8000}$th of an inch in diameter (Fig. 129); separated from each other, and lying in various directions; crossing and interlacing; some of the rows straight; others bent, and some twisted, forming irregular layers united by a kind of network. The membranes, which consist of areolar tissue, were found to present exactly the same kind of arrangement. The muscular fibre, when examined in like manner, was found to be formed of globules, also $\frac{1}{8000}$th part of an inch in diameter. Here, however, the rows of globules are always parallel. The fibres never intersect each other like those of areolar tissue, and

Fig. 129.



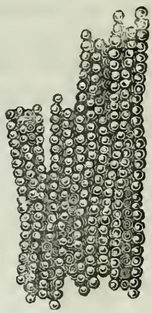
Areolar Tissue.

[1] Opera Omnia, Lugdun. Batav., 1722.
[2] De Structurâ Nervorum, Vind., 1779.
[3] Sur les Poisons, ii. 18.
[4] De Structurâ Cerebri, Tubing., 1812.
[5] Bibliothèque Universelle des Sciences et Arts, t. xvii.
[6] In Drs. Hodgkin's and Fisher's translation of W. Edwards, Sur les Agens Physiques, Lond., 1832.
[7] Klencke, Ueber das Physiologische und Pathologische Leben der Mikroskopischen Zellen, Jena, 1844.

this is the only discernible difference,—the form and size of the globules being alike. The size of the globules, and the linear arrangement they assume, seemed to be the same in all animals that possess a muscular structure. (Fig. 130.)

The nervous structure had, by almost all observers, been esteemed globular. The examination of M. Edwards yielded similar results.[1] It seemed to be composed of lines of globules of the same size as those that form the areolar membrane and muscles; but holding an intermediate place as to the regularity of their arrangement, and having a fatty matter interposed between the rows. In regard to the size of the globules, however, M. Edwards differed materially from an accurate and experienced microscopic observer, Mr. Bauer,[2] who asserted that the cerebral globules are of various sizes. (Fig. 131.) From the results of his own diversified observations M. Edwards concluded, that "spherical corpuscles, of the diameter of $\frac{1}{300}$th of a millimètre, constitute by their aggregation all the organic textures, whatever may be the properties, in other respects, of those parts, and the functions for which they are destined."

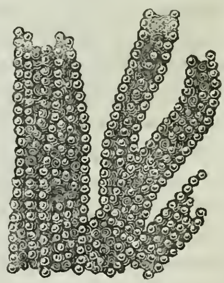
Fig. 130.



Muscular Tissue.

The harmony and simplicity, which would thus seem to reign through the structures of the animal body, attracted great attention to the labours of M. Edwards. The vegetable kingdom was subjected to equal scrutiny; and—what seemed still more astounding—it was affirmed, that the microscope proved it also to be constituted of globules precisely like those of the animal, and of the same magnitude, $\frac{1}{8000}$th of an inch in diameter; hence, it was assumed, that all organized bodies possess the same elementary structure, and of necessity, that the animal and the vegetable are readily convertible into each other under favourable circumstances, and differ only in the greater or less complexity of their organization. Independently of all other objections, however, the animal differs, as we have seen, from the vegetable, in composition; and this difference must exist not only in the whole, but in its parts; so that, even were it demonstrated that the globules of the beings of the two kingdoms are alike in size, it would by no means follow that they should be identical in intimate composition.

Fig. 131.



Nervous Tissue.

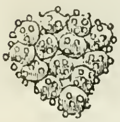
The discordance, which we have deplored, is strikingly applicable to the case before us. The appearance of the memoir of Dr. Edwards excited the attention of M. Dutrochet, and in the following year his "*Recherches*" on the subject were published, in which he asserts, that the globules, which compose the different structures of invertebrated

[1] See, also, Calori, in Bulletino delle Scienze Medich. di Bologna, Sett., 1836, p. 152.

[2] Philosoph. Transact. for 1818; and Sir E. Home, Lectures on Comparative Anatomy, vol. iii. lect. 3, Lond., 1823.

animals, are considerably larger than those of the vertebrated; that the former appear to consist of cells, containing other globules still smaller; and hence he infers, that the globules of vertebrated animals are likewise cellular, and contain series of still smaller globules. Dr. Edwards, in his experiments, found, that the globules of the nervous tissue, whether examined in the brain, in the spinal cord, ganglia, or nerves, have the same shape and diameter, and that no difference in them can be distinguished from whatever animal the tissue is taken. M. Dutrochet, on the other hand, considers, with Sir Everard Home, and the brothers Wenzel, that the globules of the brain are cellules of extreme minuteness, containing a medullary or nervous substance, which is capable of becoming concrete by the action of heat and acids. This structure, he remarks, is strikingly evidenced in certain molluscous animals; and he instances the small pulpy nucleus, which forms the cerebral hemisphere of *limax rufus*, and *helix pomatia*, and is composed of globular, agglomerated cellules, on the parietes of which a considerable number of globular or ovoid corpuscles are perceptible. (Fig. 132.)

Fig. 132.



Cellules of Brain.

M. Dutrochet, again, did not find the structure of the nerves to correspond with that of the brain. He asserted, that the elementary fibres, which enter into their composition, do not consist simply of rows of globules, according to the opinion of M. Edwards and others, but that they are cylinders of a diaphanous substance, the surface of which is studded with globular corpuscles; and that, as these cover the whole surface of the cylinder, we are led to believe that they are in the interior also. After detailing this difference of structure between the brain and the nerves, the former consisting chiefly of nervous corpuscles, the latter chiefly of cylinders or fibres, M. Dutrochet announced the hypothesis, which exhibits too many indications of having been formed prior to his microscopic investigations,—that these cerebral corpuscles are destined for the production of the nerve power, and that the nervous fibres are tubes, filled with a peculiar fluid, by the agency of which *nervimotion* is effected. For further developements of the views of M. Dutrochet, the reader is referred to the work itself, which exhibits all the author's ingenuity and enthusiasm, but can scarcely be considered historical.

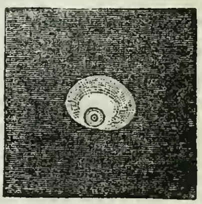
The beautiful superstructure of M. Edwards, and the ingenuity of M. Dutrochet, were, however, most fatally assailed by subsequent experiments of Dr. Hodgkin with a microscope of unusual power. The globular structure of the animal tissues, so often asserted, and apparently so clearly and satisfactorily established by M. Edwards, was, we are told by Dr. Hodgkin,[1] a mere deception; and the most minute parts of the areolar membrane, muscles, and nerves, were again referred to the striated or fibrous arrangement. A part of the discrepancy between MM. Edwards and Dutrochet may be explained by the fact of the former using an instrument of greater magnifying power than the latter, who employed the simple microscope only; and it was observed, that when the former used an ordinary lens, the arrangement

[1] Op. citat., p. 466.

of a tissue appeared cylindrical, which, with the compound microscope, was distinctly globular. The discordance between Messrs. Edwards and Hodgkin was reconcilable with more difficulty. On the whole subject, indeed, minds were kept in a state of doubt, and the rational physiologist waited for ulterior developements. MM. Prévost and Dumas, and M. Edwards, farther affirmed, that all the proximate principles—albumen, fibrin, gelatin, &c.,—assume a globular form, whenever they change from the fluid to the solid state, whatever may be the cause producing such conversion. M. Raspail[1]—a wayward genius, who has quitted the sober pursuit of science, for the uncertainty and turmoil of politics, from which he has suffered greatly—ranged himself among those who considered, that the ultimate structure of all organic textures is vesicular, and that the organic molecule, in its simplest form, is an imperforate vesicle, endowed with the faculty of inspiring gaseous and liquid substances, and of expiring again such of their elements as it cannot assimilate;—properties, which he conceived it to possess under the influence of vitality. His views contain, perhaps, the germ of those that follow, and that have since occupied so much the minds of observers.

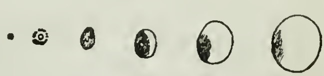
The microscopical researches of Schwann and Schleiden[2] led them to affirm, that the new-forming tissues of vegetables originate from a liquid gum or vegetable mucus, and those of animals probably from the liquor sanguinis, after transudation from the capillary vessels. This *matrix*, in a state fully prepared for the formation of the tissue, is termed by them *intercellular substance* and *cytoblastema*. In the first instance, it exhibits minute granular points, which grow and become more regular and defined from the agglomeration of minuter granules around the larger, constituting *nuclei* or *cytoblasts* or *cell-germs*, and having, when fully formed, and in fact formed before them, one or more well-defined bodies within, called *nucleoli*. From the cytoblasts, *cells—primordial* or *germinal cells*—are formed. A transparent vesicle grows over each, and becomes filled with fluid; this gradually extends and becomes so large that the cytoblast appears like a small body within its walls, and hence the cell is said to be *nucleated*. The form of the cells is at first irregular, then more regular, and they are alternately flattened by pressure against each other, so as to assume different forms in different tissues. Such is the description of Schwann and Schleiden of the vegetable cells from which all the tissues of

Fig. 133.



Primary Organic Cell, showing the germinal Cell, Nucleus, and Nucleolus.

Fig. 134.



Plan representing the formation of a Nucleus, and of a Cell on the Nucleus, according to Schleiden's view.

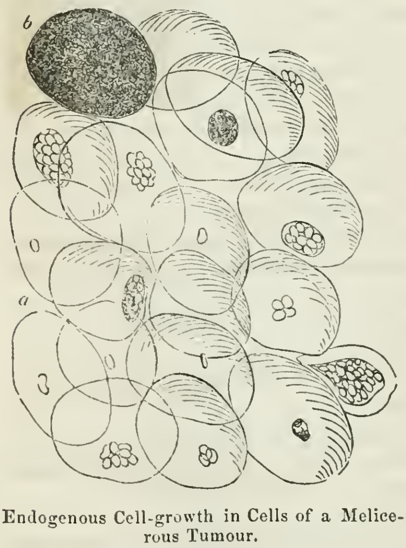
[1] Op. citat., § 126.

[2] Mikroskopische Untersuchungen über die Uebereinstimmung in der Struktur und dem Wachstum der Thiere und Pflanzen, von Dr. Th. Schwann und Dr. Schleiden, in Müller's Archiv., p. 137, 1838; and Microscopical Researches into the Accordance and Growth of Animals and Plants, translated by Henry Smith, Sydenham Society's edition, London, 1847.

plants take their origin. In like manner, the tissues of animals are formed from a fluid, in which *nucleoli*, *nuclei* or *cytoblasts*—and *cells*, are successively developed. The globules of lymph, pus, and mucus, are cells with their walls distinct and isolated from each other; horny tissues are cells with distinct walls, but united into coherent tissues; bone, cartilage, &c., are formed of cells whose walls have coalesced; areolar tissue, tendon, &c., are cells which have split into fibres; and muscles, nerves, and capillary vessels are cells whose walls and cavities have coalesced.

These cells seem to possess an independent and limited life, which has no immediate connexion with that of the organism; the decomposition constantly taking place in the living body being connected with the death of the cells of which the several parts are constructed; and for the reintroduction of which into the circulating fluid, the lymphatic system appears to be specially destined. By virtue of this vital power, they not only attract but change the substances brought in contact with them, or have a power of self-nutrition; and that this is probably independent of the nervous system is shown by an experiment of Dr. Sharpey, in which the reproduction of a portion of the tail of a salamander took place, although it was cut off after the organ had been completely paralyzed by dissecting out at its root a portion of the spinal cord, together with the arches of the vertebræ. To the doctrine of cell formation, Professor Goodsir,[1] of Edinburgh, has, of late years, made several important additions. Amongst other observations, he states, that besides all organs and tissues having their origin in and consisting essentially of simple or developed cells possessed of a special independent vitality, the component cells are divided into numerous departments, each of which consists of several cells arranged round one central or capital cell, which latter is the source whence all the other cells in its own department derived their origin. To each of these several central nucleated cells he gives the name *nutritive centre* or germinal spot. Each nutritive centre possesses the power of absorbing materials of nourishment from the surrounding vessels, and of generating, by means of its nucleus, successive broods of young endogenous cells, which from time to time fill the cavity of the parent cell, and, carrying with them its cell-wall, pass off in certain directions, and under

Fig. 135.



Endogenous Cell-growth in Cells of a Melicerous Tumour.

a. Cells presenting nuclei in various stages of developement into a new generation. *b*. Parent-cell filled with a new generation of young cells, which have originated from the granules of the nucleus.

[1] Anatomical and Pathological Observations, p. 1, Edinb., 1845.

various forms, according to the texture or organ of which the parent forms a part. There are two kinds of nutritive centres,—those peculiar to the textures, and those belonging to organs. The former are in general permanent; the latter peculiar mostly to the embryonic state, and ultimately disappearing; but there is one form in which the nutritive centres are arranged both in healthy and morbid parts, which constitutes what Mr. Goodsir calls a *germinal membrane*. It is only met with on the free surface of organs or parts. It is a fine transparent membrane, consisting of cells arranged at equal and variable distances within it. The centres of these component cells are flattened, so that their walls form the membrane by cohering at their edges, and their nuclei remain in its substance as germinal centres. One surface of the membrane is attached to that of the organ or part, and is, therefore, applied upon a more or less richly vascular tissue; the other is free, and it is to it only that the developed or secondary cells of its germinal spots are attached. These secondary cells, whilst forming, are contained between the two layers of the germinal membrane; but as they become developed, they carry forward the anterior layer, and become attached to the free surface, whilst the nuclei are left in the substance of the posterior layer in close contact with the bloodvessels, from which they derive the materials for the formation of new cells.

The doctrine of the developement of all the organic tissues from cells is now embraced by almost all histological inquirers; yet there are some who doubt it; and others, who by no means regard it as applicable to all the tissues. Thus M. Mandl[1] objects to the term *cytoblastema* as applicable to the matrix or organizing material of the tissues, because it necessarily involves the supposition that it gives origin to cells. According to him, the elements, that are developed in the *blastema*—as he prefers to call it—do not generally deserve the name of cells, inasmuch as they may either liquefy as in the glands; consolidate as in the amorphous membranes; or become transformed directly into fibres, as in the areolar tissue. Mr. Gulliver,[2] too, has inferred from his observations, that the mere extension of the parietes of cells is not essential to the formation of all tissues, since fine fibres or fibrils are found in fibrin that has coagulated even out of the body. He has given several figures to exhibit the analogy of structure between false membranes and fibrin coagulated after death, or after the removal of the blood from the body. Schwann, on the other hand, lays down the rule, which he considers of universal application, that all organic tissues, however different they may be, have one common principle of developement as their basis, the formation of cells;—that is to say, nature never unites molecules immediately into a fibre, tube, &c.; but, always, in the first instance, forms a round cell; or changes, when it is requisite, the cells into the various primary tissues, as they present themselves in the adult state; but "how," says Mr. Gulliver,[3] "is the origin of the fibrils, which I have depicted in so many varieties of fibrin, to be reconciled with this doctrine? and what is the proof that

[1] Manuel d'Anatomie Générale, p. 549, Paris, 1843.
[2] Appendix to Gerber's Anatomy, Atlas, p. 60, and Figs. 244–6, Lond., 1842.
[3] Lond. and Edinburgh Philosoph. Magazine, Oct., 1842.

these fibrils may not be the primordial fibres of animal textures? I could never see any satisfactory evidence, that the fibrils of fibrin are changed cells; and, indeed, in many cases, the fibrils are formed so quickly after coagulation, that their production, according to the views of the eminent physiologist just quoted [Schwann], would hardly seem possible. Nor have I been able to see, that these fibrils arise from the interior of the blood-disks, like certain fibres delineated in the last interesting researches of Dr. Barry." Mr. T. Wharton Jones,[1] also, has considered the notion entertained by Dr. Barry,[2] that a fibre exists in the interior of the blood corpuscles, and that these fibres, after their escape from them, constitute the fibres which are formed by the consolidation of the fibrin of the liquor sanguinis, to be erroneous. He regards the appearance as altogether illusive. Dr. Carpenter,[3] in remarking on Mr. Gulliver's figures, all of which, as he properly observes, clearly show, that a small portion of coagulated fibrin contains a far larger number of fibres than we can imagine to be contained in the number of blood-disks that would fill the same space, states, that he has discovered a very interesting example of a membrane composed almost entirely of matted fibres, which so strongly resembles the delineations of fibrous coagula given by Mr. Gulliver, that he cannot but believe in the identity of the process by which they are produced. This is the membrane enclosing the white of the egg, and forming the animal basis of the shell. If the shell be treated with dilute acid, a tough membrane remains, exactly resembling that which lines it; and if the hen has not been supplied with lime, there is no difference between the two membranes even without the action of acid on the outer one. Each of them consists of numerous laminæ of most beautifully matted fibres intermixed with round bodies exactly resembling exudation cells. It is in the interstices of these fibres, that the calcareous particles are deposited, which give density to the shell. These membranes, according to Dr. Carpenter, are formed around the albumen, which is deposited on the surface of the ovary during its passage along the oviduct, from the interior of which the fibrinous exudation must take place.

It is clear, then, that this doctrine of the origin of all the tissues from cells cannot be considered established.[4] Nor can ideas be esteemed more fixed in regard to the character of the matrix or blastema. M. Mandl[5] affirms that we know not whether it is the albumen or fibrin of the blood. Others, and perhaps the majority of the present day, ascribe it to fibrin, between which, as we have elsewhere seen, and albumen, there is, according to Mulder, Liebig, and others, an almost identity of chemical composition. Fibrin has been considered—but, as is remarked

[1] Proceedings of the Royal Society, No. 56. [2] Philos. Trans. for 1842.

[3] Origin and Functions of Cells, in Brit. and For. Med. Rev. for Jan., 1843, p. 277. See also The Cell: its Physiology, Pathology, and Philosophy, by Waldo J. Burnett, M. D., in Transactions of the American Medical Association, vi. 645, Philad., 1853; and T. H. Huxley on the Cell Theory, in Brit. and For. Med.-Chirurg. Rev. for Oct., 1853, p. 285.

[4] "Cette pièrre angulaire de la physiologie microscopique"—says a recent writer—"est donc une véritable pomme de discorde. Cela est vraiment dommage; car cette doctrine est si non convainçante du moins fort amusante." J. L. Brachet, Physiologie Élémentaire de l'Homme, 2de édit., i. 25, Paris and Lyons, 1855.

[5] Op. cit., p. 548.

elsewhere, on insufficient grounds—to possess higher properties; and the change of albumen into fibrin has been esteemed the first important step in the process of assimilation. In the chyliferous vessels, the proportion of fibrin increases as the chyle and lymph proceed onwards in the vessels; whilst that of the albumen diminishes. Such, however, is not rigorously the fact, for on referring to the table slightly modified from that of Gerber, which has been given elsewhere (p. 227), it will be seen, that in the afferent lacteals between the intestines and mesenteric glands, the albumen has been found in *minimum* quantity; in the efferent or central lacteals, from the mesenteric glands to the thoracic duct, in *maximum* quantity; and in the thoracic duct in *medium* quantity; whilst the fibrin goes on progressively increasing as the chyle and lymph proceed onwards. On the other hand, the fat was found to diminish progressively; so that there appears to be more probability that the fibrin is formed from the fat, directly or indirectly, than from the albumen.

It would seem not improbable,—as before remarked,[1]—that some nitrogenized material like pepsin, or diastase in plants, is secreted from the parietes of the chyliferous vessels, which occasions a change in the constituents of the chyle; and the view is somewhat confirmed by the fact to which attention has been drawn by Mr. G. Ross,[2] that the constituents of fatty matter, added to those of uric acid, would very nearly give the atomic constituents of albumen; whence, as Dr. Carpenter[3] has remarked, it might be surmised, that when there is a demand for proteinaceous compounds in the system, nitrogenized matter, which would otherwise be thrown out of the system, may be united with non-nitrogenized compounds taken as food, in order to supply its wants. That there is an essential physiological difference, however, between fibrin and albumen, notwithstanding their affirmed similarity in chemical composition, is shown by the fact, that effused fibrin has a tendency to spontaneous coagulation, whilst albumen requires the agency of heat. This difference in properties would necessarily induce the belief, that the two substances differ more perhaps in chemical composition than the results of the analyses of Mulder, Liebig, and others, would seem to indicate; and such appears to be proved by those of MM. Dumas and Cahours, which have been conducted on a very extensive scale; and show, that the proportion of carbon is seven per cent. less in fibrin than in albumen; whilst that of nitrogen is from eight to nine per cent. more. A correct idea, these gentlemen think, may be formed of the elementary composition of fibrin by considering it a compound of casein, albumen, and ammonia.[4]

It has been previously shown,[5] that there is great reason to doubt, that fibrin is the main material employed in nutrition; and that arguments have been brought forward to establish, that it is rather the product of a retrograde change of the albuminous matters. The comparatively small quantity in which it is present in the liquor sanguinis does not favour the view, that it alone is the pabulum for the higher nutritive acts.

A view is entertained by many, that nothing but proteinaceous com-

[1] Page 226. [2] Lancet, 1842–3, vol. i. [3] Op. cit., p. 492.
[4] Med. Examiner, October 14, 1843, p. 232. [5] Page 49.

pounds can serve for the nutrition of the tissues; and that gelatin is not adapted for this purpose. Liebig suggests, that it may be inservient to the nutrition of the gelatinous tissues; and Dr. Carpenter[1] says, there is no doubt, that it is incapable of being applied to the reconstruction of any but those tissues; and that it seems questionable, whether, even in those, it exists in a condition that can rightly be termed organized: yet it appears to the author, that no doubt ought to be entertained on the matter. The inconclusiveness of the experiments made on gelatin as an article of food has been animadverted on elsewhere (p. 113). Although not a proteinaceous compound, it is one that is highly nitrogenized. When used as an aliment, it is not capable of being detected in the chyle or blood, and hence must have undergone a metamorphosis, probably into an albuminous compound; and it is certainly as difficult to comprehend how, under such circumstances, gelatin can be inservient to the nutrition of gelatinous tissues when no gelatin is present in the blood, as to comprehend that it may be converted into albumen. How gelatinous aliment, in other words, is formed into chyle and blood in which gelatin is not discoverable, and from these again gelatinous tissues are re-formed, is as incomprehensible as that any of the proteinaceous tissues should be constituted from the same pabulum; or that oleaginous aliments—as is admitted by some, who deny the same power to the gelatinous—should be convertible into proteinaceous compounds.

Such is the state of uncertainty in which we are compelled to rest in regard to this important function. None of the views can be esteemed established. They are in a state of transition; and all, perhaps, that we are justified in deducing hypothetically is, that the vital force, which exists in the blastema furnished by the parents at a fecundating union, gives occasion to the formation of cells, and that the tissues are farther developed through the agency of *cell-life*, so as to constitute most of the textures of which the body is composed.

It is the action of nutrition, that occasions the constant fluctuations in the weight and size of the body, from the earliest embryo condition till advanced life. The cause of the *growth* of organs and of the body generally, as well as of the limit accurately assigned to such growth, according to the animal or vegetable species, is dependent upon vital laws that are unfathomable. Nor are we able to detect the precise mode in which the growth of parts is effected. It cannot be simple extension, for the obvious reason that the body and its various compartments augment in weight as well as in dimension. The rapidity with which certain growths are effected is astonishing. The *Bovista giganteum* has been known to increase, in a single night, from a mere point to the size of a large gourd, estimated to contain 48,000,000,000 of cellules; and supposing twelve hours to have been necessary for its growth, the cells in it must have been produced at the rate of 4,000,000,000 an hour, or more than 66,000,000 a minute,—the greater part of the elements necessary for this astonishing formation being obtained from the air.[2] But

[1] Principles of Human Physiology, 2d edit., p. 476, London, 1844. In the last edition of his work (p. 64, Philad.. 1855) he doubts, whether it can even go to the nutrition of the gelatinous tissues; and expresses the opinion, doubtless—the author thinks—to be equally abandoned hereafter, that its alimentary value "must be limited to its calorific power."

[2] Truman, Food and its Influence on Health and Disease, &c., p. 229, Lond., 1842.

these rapid growths possess little vitality, and their decay is almost as rapid as their production. Analogous growths—but not to the like extent—occur in the human body, and the same remark applies to them.

In the large trees of our forests we find a fresh layer or ring added each year to the stem, until the full period of developement; and it has been supposed that the growth of the animal body may be effected in a similar manner, both as regards its soft and harder materials,—that is, by layers deposited externally. That the long bones lengthen at their extremities is proved by an experiment of Mr. Hunter.[1] Having exposed the tibia of a pig, he bored a hole into each extremity of the shaft, and inserted a shot. The distance between the shots was then accurately taken. Some months afterwards, the same bone was examined, and the shots were found at precisely their original distance from each other; but the extremities of the bone had extended much beyond their first distance from them. The flat bones also increase by a deposition at their margins; and the long bones by a similar deposition at their periphery,—additional circumstances strongly exhibiting the analogy between the successive developement of animals and vegetables. Exercise or rest; freedom from, or the existence of, pressure, produces augmentation of the size of organs, or the contrary; and there are certain medicines, as iodine, which are said to occasion emaciation of particular organs only—as of the female mammæ. The effect of disease is likewise, in this respect, familiar and striking.[2]

The ancients had noticed the changes effected upon the body by the function we are considering, and attempted to estimate the period at which a thorough conversion might be accomplished, so that not one of its quondam constituents should be present. By some, this was held to be seven years; by others, three. It is hardly necessary to say, that in such a calculation we have nothing but conjecture to guide us. The nutrition of the body and its parts varies, indeed, according to numerous circumstances. It is not the same during the period of growth as subsequently, when absorption and deposition are balanced,—so far, at least, as concerns the augmentation of the body in one direction. Particular organs have, likewise, their period of developement, at which time the nutrition of such parts must necessarily be more active,—the organs of generation, for example, at the period of puberty; the enlargement of the mammæ in the female; the appearance of the beard and the amplification of the larynx in the male, &c. All these changes occur after a determinate plan.

The activity of nutrition appears to be increased by exercise, at least in muscular organs; hence the well-marked muscles of the arm in the prize-fighter, of the legs in the dancer, &c. The muscles of the male are, in general, much more clearly defined; but the difference between those of the hard-working female and the inactive male may not be very apparent.

The most active parts in their nutrition are the glands, muscles, and skin, which alter their character—as to size, colour, and consistence—

[1] Observations on Certain Parts of the Animal Economy, with notes, by Prof. Owen, Amer. edit., p. 321, Philad., 1840.

[2] The author's General Therapeutics and Mat. Med., 5th edit., Philad., 1853; and his Practice of Medicine, 3d edit., Philad., 1848.

with great rapidity; whilst the tendons, fibrous membranes, bones, &c., are much less so, and are altered more slowly by the effect of disease. A practice, which prevails amongst certain professions and people, would seem, at first sight, to show that the nutrition of the skin cannot be energetic. Sailors are in the habit of forcing gunpowder through the cuticle with a pointed instrument, and of figuring the initials of their names upon the arm in this manner: the particles of the gunpowder are thus driven into the cutis vera, and remain for life. The operation of *tattooing*, or of puncturing and staining the skin, prevails in many parts of the globe, and especially in Polynesia, where it is looked upon as greatly ornamental. The art is said to be carried to its greatest perfection in the Washington or New Marquesas Islands;[1] where the wealthy are often covered with various designs from head to foot; subjecting themselves to a most painful operation for this strange kind of personal decoration. The operation consists in puncturing the skin with some rude instrument, according to figures previously traced upon it, and rubbing into the punctures a thick dye, frequently composed of the ashes of the plant that furnishes the colouring matter. The marks, thus made, are indelible. M. Magendie[2] asks:—"How can we reconcile this phenomenon with the renovation, which, according to authors," (and he might have added, according to himself,) "happens to the skin?" It does not seem to us to be in any manner connected with the nutrition of the skin. The colouring matter is an extraneous substance, which takes no part in the changes constantly going on in the tissue in which it is embedded; and the circumstance seems to afford a negative argument in favour of venous absorption. Had the substance possessed the necessary tenuity, it would have entered the veins like other colouring matters; but the particles are too gross for this, and hence remain free from all absorbing influence.

Fig. 136.

Tattooed Head of a New Zealand Chief.

Like the other organic functions, nutrition does not require the presence of a nervous system. The beautiful products of the vegetable kingdom sufficiently demonstrate that it can be accomplished without one; and in the primordial cell, from which the new being in man and animals is formed, we may in vain look for anything resembling a nervous system. Generally by those who believe in the necessity of a nervous system for the execution of this as well of every other or-

[1] Lawrence, Lectures on Physiology, &c., p. 411, Lond., 1819.
[2] Précis, &c., edit. cit., ii. 483.

ganic act, the action of the sympathetic is invoked; others have assigned great influence to the spinal marrow. M. Brown-Séquard,[1] however, found that birds are able to live for months after the destruction of the spinal cord from the fifth costal vertebra to its termination; and if the operation has been performed on a young bird, it will continue to grow well. He succeeded in keeping alive a young cat from the 8th of April until the 4th of July, after that part of the cord, which extends from the 11th or 12th costal vertebra to the sacrum had been destroyed. Although paraplegic, the palsied parts had grown in length proportionately as much as the sound parts; and they had acquired more than double the length which they had at the time of the operation. The functions of organic life appeared to be carried on without any apparent disturbance, and the nutritive reparation was so powerful, that the portions of the vertebral column which had been cut off were reproduced. In birds on which the operation had been practised he found that the secretion of quills and nails continued to take place.

Yet although nutrition can be accomplished without a nervous system; its intensity can be materially modified in man and animals by nervous influence; and in this way we must account for the effects occasionally induced on tumours by the efforts of the animal magnetizer, for example.

CHAPTER VI.

SECRETION.

We have next to describe an important and multiple function, which also takes place in the intermediate system—in the very tissue of our organs—and separates from the blood the various humours. This is the function of *secretion*,—a term literally signifying *separation*—and which has been applied both to operation and product. Thus, the liver is said to separate the bile from the blood by an action of secretion, and the bile is said to be a secretion.

The organs that execute the various secretory operations differ greatly from each other. They have, however, been grouped by anatomists into three classes, each of which will require a general notice.

1. ANATOMY OF THE SECRETORY APPARATUS.

The secretory organs have been divided into the *exhalant*, *follicular*, and *glandular*.

The remarks made respecting the *exhalant vessels* under the head of Nutrition render it unnecessary to allude, in this place, to any of the apocryphal descriptions of them, especially as their very existence is supposititious.

A simple *follicle* or *crypt* has the form of an ampulla or vesicle, and is situate in the substance of the skin and mucous membranes; secreting a fluid for the purpose of lubricating them. In the capillary ves-

[1] Med. Examiner, May, 1852, p. 321, and August, 1852, p. 495.

sel, the secreted fluid passes immediately from the bloodvessel, without being received into any excretory duct; and, in the simplest follicle, there is essentially no duct specially destined for the excretion of the humour. It is membranous and vascular, having an internal cavity into which the secretion is poured; and the product is excreted upon the surface beneath which it is situate, either by a central aperture, or by a very short duct—if duct it can be called—generally termed a *lacuna*. Many of the so called follicles are, however, more complicated, and consist, like the Meibomian, of various *cul-de-sacs*, with separate ducts which open into one; so that the distinction between a compound follicle and a gland is not easily made; and physiologically no difference can be considered to exist.

The *gland* is of a more complex structure than the simple follicle. It consists of an artery which conveys blood to it; of an intermediate body,—the *gland*, properly so called,—and of an excretory duct to carry off the secreted fluid, and to pour it on the surface of the skin or mucous membrane. The bloodvessel, that conveys to the gland the material from which the secretion has to be effected, enters the organ,—at times, by various branches; at others, by a single trunk; and ramifies in the tissue of the gland; communicating at its extremities with the origins of the veins and indirectly with the excretory ducts. These ducts arise by fine radicles at the part where the arterial ramifications terminate; and they unite to form larger and less numerous canals, until they end in one large duct, as in the pancreas; or in several, as in the lachrymal gland,—the duct generally leaving the gland at the part where the bloodvessel enters. Of this there is a good exemplification in the kidney.

The pavement and the cylinder epithelium, as well as all the intermediate forms, are met with in the different glands. These are not necessarily a continuation of the epithelium of the cutaneous system; on the contrary, that of the latter is often seen changing its form at its entrance into the gland.

Besides the vessels above mentioned, veins exist, which communicate with the bloodvessels that convey blood to the gland, both for the formation of the humour and the nutrition of the organ; and which return the residuary blood to the heart. Lymphatic vessels are likewise there; and nerves,—proceeding from the ganglionic system,—form a network around the secreting arteries, accompany them into the interior of the organ, and terminate, like them, invisibly. Bordeu[1] was of opinion, that the glands, judging from the parotid, are largely supplied with nerves. They do not, however, all belong to it, some merely crossing it in their course to other parts. Bichat,[2] from the small number sent to the liver, was induced to draw opposite conclusions to those of Bordeu.

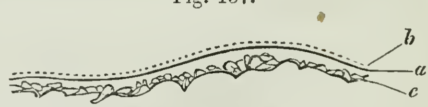
These may be looked upon as the great components of the glandular structure. They are bound together by areolar tissue, and have generally an outer envelope. The intimate texture of these organs has been a topic of much speculation. It is generally considered, that the final

[1] Sur les Glandes, in Œuvres Complètes, par M. Richerand, Paris, 1818.
[2] Anat. Général., tom. ii.

ramifications of the arterial vessels, with the radicles of the veins and excretory ducts, and the final ramifications of the lymphatic vessels and nerves, form so many small lobules, composed of minute granular masses. Such, indeed is the appearance the texture presents when examined by the naked eye. Each lobule is conceived to contain a final ramification of the vessel or vessels that convey blood to the organ, a nerve, a vein, a lymphatic, and an excretory duct,—with areolar tissue binding them together. When the organ has an external membrane, it usually forms a sheath to the various vessels. The lobated structure is not equally apparent in all the glands. It is well seen in the pancreas, salivary and lachrymal.

The precise mode in which the vessel, from the blood of which the secretion is effected, communicates with the excretory duct, does not admit of detection. Professor Müller[1] maintains, that the glandular structure consists essentially of a duct with a blind extremity, on whose parietes plexuses of bloodvessels ramify, from which the secretions are immediately made,—a view which was confirmed by the pathological appearances, in a case of disease of the portal system that fell under the author's observation, and is referred to hereafter. The opinion of Malpighi[2] was similar. He affirmed that such glands as the liver are composed of very minute bodies, called *acini* from their resemblance to the stones of grapes;—that these acini are hollow internally, and covered externally by a network of bloodvessels; and that these minute bloodvessels pour into the cavities of the acini the secreted fluid, from which it is subsequently taken up by the excretory ducts. Ruysch,[3] however, held, that the acini of Malpighi are merely convoluted vessels, continuous with the excretory ducts. In Malpighi's view, the secretory organ is a mere collection of follicles; in Ruysch's, simply an exhalant membrane, variously convoluted. "The chief, if not the only difference," says a popular writer,[4] "between the secreting structure of glands and that of simple surfaces, appears to consist in the different number and the different arrangement of their capillary vessels. The actual secreting organ is in both cases the same,—capil-

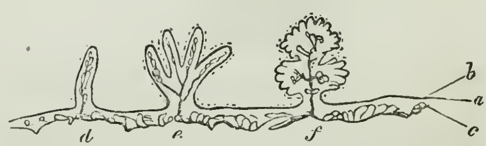
Fig. 137.



Plan of a Secreting Membrane.

a. Membrana propria or basement membrane. *b.* Epithelium, composed of secreting nucleated cells. *c.* Layer of capillary bloodvessels.

Fig. 138.



Plan to show augmentation of Surface by formation of Processes.

a, b, c. As in preceding figure. *d.* Simple, and *e, f,* branched or subdivided processes.

[1] De Glandular. Secernent. Structurâ Penitiori, &c., Lips., 1830; or the English edit. by Mr. Solly, Lond., 1839.

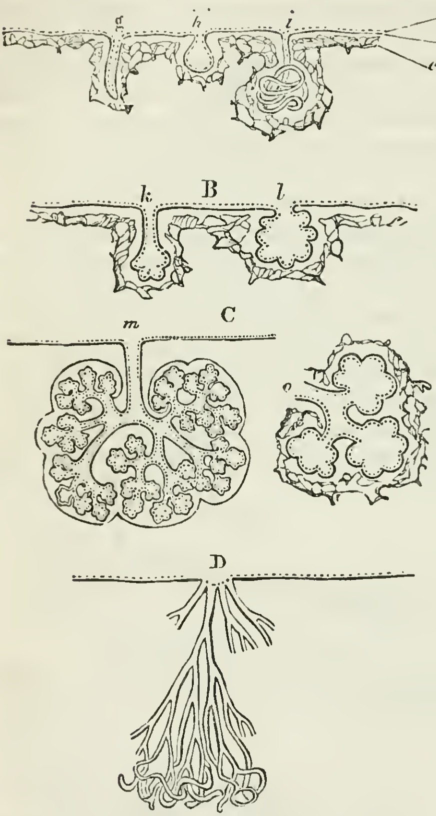
[2] Opera Omnia, &c., p. 300, Lugd. Batav., 1687.

[3] Epist. Anatom. quâ respondet Viro Clarissimo Hermann. Boerhaav., p. 45, Lugd. Batav., 1722.

[4] Southwood Smith, in Animal Physiology, p. 115; Library of Useful Knowledge, Lond., 1829.

lary bloodvessel; and it is uncertain whether either its peculiar arrangement, or greater extent in glandular texture, is productive of any other effect than that of furnishing the largest quantity of bloodvessels within the smallest space. Thus convoluted and packed up, secreting organ may be procured to any amount that may be required, without the inconvenience of bulk and weight."

Fig. 139.



Plans of extension of Secreting Membrane, by inversion or recession in form of cavities.

A. Simple glands, viz., *g*, straight tube, *h*, sac, *i*, coiled tube. B. Multilocular crypts, *k*, of tubular form, *l*, saccular. C. Racemose or vesicular compound glands. *m*. Entire gland, showing branched duct and lobular structure. *n*. A lobule, detached with *o*, branch of duct proceeding from it. D. Compound tubular gland.

It is manifest, that the simplest form of the secretory apparatus consists of simple capillary vessel, and animal membrane; and that the follicles and glands are structures of a more complex organization, but still essentially identical; — all perhaps—as will be seen presently—executing their functions by means of cell agency. Or, to use the views and language of the day, every secreting organ possesses, as essential parts of its structure, a simple and apparently anhistous or textureless membrane, called *primary* or *basement membrane; cells* and *bloodvessels;* and by some, all the various modes in which these three structural elements are arranged have been classed under one or other of two principal divisions—*membranes*, and *glands*.[1]

Some of the glands, as the lacteal and salivary, are granular in their arrangement; others, as the spermatic and urinary, consist of convoluted tubes; but all may be regarded as a prolongation of the skin; and the essential difference between the various secretory organs is in the extent occasionally of eversion but generally of inversion and convolution of the secretory membrane. This is well represented in the marginal figures.[2] The morphology of the secretory apparatus has

[1] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 238, Philad., 1849.

[2] Quain's Human Anatomy by Quain and Sharpey, Amer. edit. by Leidy, ii. 99, Philad., 1849.

been carefully investigated; but here—as elsewhere—we remain ignorant of the vital processes concerned. "We must not,"—says Liebig[1] —"forget that anatomy alone, from the days of Aristotle to Leeuenhoek's time, has thrown but a partial light upon the laws of the phenomena of life. As a knowledge of the apparatus of distillation does not instruct us alone concerning its uses; so in many processes, as in distillation, he who understands the nature of fire, the laws of the diffusion of heat, and of evaporation, the construction of the still, and the products of distillation,—knows infinitely more of the process of distillation than the smith himself who made the apparatus. Each new discovery in anatomy has added acuteness, exactitude, and extent to its descriptions; unwearied investigation has almost penetrated to the inmost cell, from whence a new road of inquiry must be opened."

2. PHYSIOLOGY OF SECRETION.

The uncertainty which has rested on the intimate structure of secreting organs, and on the mode in which the different bloodvessels communicate with the commencement of the excretory duct, has enveloped the function, executed by those parts, in obscurity. We see the pancreatic artery pass to the pancreas; ramify in its tissues; become capillary, and escape detection; and other vessels becoming larger and larger, and emptying themselves into vessels of greater magnitude, until, ultimately, all the secreted humour is contained in one large duct, which passes onwards, and discharges its fluid into the small intestine. Yet if we follow the pancreatic artery as far back as the eye can carry us, even when aided by glasses of considerable magnifying power, or if we trace back the pancreatic duct, we find, in the former vessel, always arterial blood, and in the latter, always pancreatic fluid. It must, consequently, be between the part at which the artery ceases to be visible, and at which the pancreatic duct becomes so, that secretion is effected.

Conjecture, in the absence of positive knowledge, has been busy, at all times, in attempting to explain the mysterious agency by which such various humours are separated from the same fluid; and, according as chemical, or mechanical, or exclusively vital doctrines have prevailed in physiology, the function has been referred to one or other of those agencies. The general belief amongst the physiologists of the sixteenth and seventeenth centuries was, that each gland possesses a peculiar kind of fermentation, which assimilates to its own nature the blood passing through it. The notion of fermentation was, indeed, applied to most of the vital phenomena. It is now totally abandoned, owing to its being purely imaginary, and inconsistent with all our ideas of the vital operations. When this notion had passed away, and the fashion of accounting for physiological phenomena on mechanical principles took its place, the opinion prevailed, that the secretions are effected through the glands as through filters. To admit of this mechanical result, it was maintained, that all the secreted fluids exist ready formed in the blood, and that, when they arrive at the different secretory organs, they pass through, and are received by, the excretory ducts.

[1] Chemistry and Physics in relation to Physiology and Pathology, p. 105, Lond., 1846.

Des Cartes[1] and Leibnitz[2] were warm supporters of this mechanical doctrine, although their views differed materially with regard to the precise nature of the operation. Des Cartes supposed, that the particles of the various humours are of different shapes, and that the pores of the glands have a corresponding figure; so that each gland permits those particles only to pass through it which have the shape of its pores. Leibnitz, on the other hand, likened the glands to filters, which had their pores saturated with their own peculiar substance, so that they admitted it to pass through them, and excluded all others,—as paper, saturated with oil, prevents the filtration of water. The mechanical doctrine of secretion was taught by Malpighi and Boerhaave,[3] and continued to prevail until the time of Haller. All the secretions were conceived to be ready formed in the blood, and the glands were looked upon as sieves or strainers to convey off the appropriate fluids or humours. In this view of the subject, all secretion was a transudation through the coats of the vessels,—particles of various sizes passing through pores respectively adapted for them.[4]

The mechanical doctrine of transudation, in this shape, is founded upon supposititious data; and the whole facts and arguments are so manifestly defective, that it is now abandoned. MM. Magendie and Fodéra have, however, revived the mechanical view of late years; but under an essentially different form, and one especially applicable to the exhalations. The former gentleman,[5] believing that many of these exist ready formed in the blood, thinks that the character of the exhaled fluid is dependent upon the physical arrangement of the small vessels, and his views repose upon the following experiments. If, in the dead body, we inject warm water into an artery passing to a serous membrane, as soon as the current is established from the artery to the vein, a multitude of minute drops may be observed oozing through the membrane, which speedily evaporate. If, again, a solution of gelatin, coloured with vermilion, be injected into the vessels, it will often happen, that the gelatin is deposited around the cerebral convolutions, and in the anfractuosities, without the colouring matter escaping from the vessels, whilst the latter is spread over the external and internal surfaces of the choroid. If, again, linseed oil, also coloured with vermilion, form the matter of the injection, the oil, devoid of colouring matter, is deposited in the articulations which are furnished with large synovial capsules; and no transudation takes place at the surface of the brain, or in the interior of the eye. M. Magendie asks, if these be not instances of true secretion taking place *post mortem*, and evidently dependent upon the physical arrangement of the small vessels; and whether it be not highly probable, that the same arrangement must, in part at least, preside over exhalation during life. M. Fodéra,[6] to whose experiments on the imbibition of tissues we had occasion to allude under the head of Absorption, embraces the views of M. Ma-

[1] De Homine, p. 11, Lugd. Bat., 1664. [2] Haller, Element. Physiol., vii. 3.
[3] Prælectiones Academicæ, &c., edit. A. Haller, § 253, Gottin., 1740–1743.
[4] Mascagni, Nova per Poros Inorganicos Secretionem Theoria., Rom., 1793, tom. ii.
[5] Précis, &c., edit. cit., ii. 444.
[6] Magendie's Journal de Physiologie, iii. 35; and Recherches, &c., sur l'Absorption et l'Exhalation, Paris, 1824.

gendie, and so does Valentin.[1] If the vessels of a dead body, M. Fodéra remarks, be injected, the substance of the injection is seen oozing through them; and if an artery and a vein be exposed on a living animal, a similar oozing through the parietes is observable. This is more manifest if the trunk, whence the artery originates, be tied,—the fluid being occasionally bloody. If the jugular veins be tied, not only does œdema occur in the parts above the ligatures, but there is an increase of the salivary secretion. It is not necessary to refer to the various experiments of Fodéra relating to this topic, or to those of Harlan, Lawrence and Coates, Dutrochet, Faust, Mitchell, and others. They are of the same character as those previously alluded to when treating of the imbibition of tissues; for transudation is only imbibition or soaking from within to without. MM. Magendie and Fodéra, indeed, conclude, that imbibition is a primary physical cause of exhalation as it is of absorption.

Another physical cause, adduced by M. Magendie, is the pressure experienced by the blood in the circulatory system, which, he thinks, contributes powerfully to cause the more aqueous part to pass through the coats of the vessels. If water be forcibly injected through a syringe into an artery, all the surfaces, to which the vessel is distributed, as well as the larger branches and the trunk itself, exhibit the injected fluid oozing in greater abundance according to the force exerted in the injection. He farther remarks, that if water be injected into the veins of an animal, in sufficient quantity to double or treble the natural amount of circulating fluid, a considerable distension of the circulatory organs is produced, and the pressure is largely augmented. If any serous membrane be now examined,—as the peritoneum,—a watery fluid is observed issuing rapidly from it, which accumulates in the cavity, and produces a true dropsy under the eye of the experimenter; and, occasionally, the colouring part of the blood transudes at the surface of certain organs, as the liver, spleen, &c.

Hamberger, again, broached the untenable physical hypothesis, that each secreted humour is deposited in its proper secretory organ by virtue of its specific gravity,[2]—but all these speculations proceed upon the belief, that the exhalations exist ready formed in the blood; and that, consequently, the act of secretion, so far as concerns them, is one of separation or secerning,—not of fresh formation. That this is the case with the more aqueous secretions is probable, and not impossible with regard to the rest. Organic chemistry is subject to more difficulties in the way of analysis than inorganic; and it can be understood, that in a fluid so heterogeneous as the blood the discovery of any distinct humour may be impracticable. Of course, the elements of every fluid, as well as solid, must be contained in it; and we have already seen, that not merely the inorganic elements, but the organic or compounds of organization have been detected in it by the labours of Chevreul and others. There are indeed, some singular facts connected with this subject. MM. Prévost and Dumas,[3] having removed

[1] Lehrbuch der Physiologie des Menschen, Bd. 1, s. 601, Braunschweig, 1844.
[2] Adelon, Physiologie de l'Homme, 2de édit., iii. 455, Paris, 1829.
[3] Annales de Chimie, tom. xxii. and xxxiii. 90.

the kidneys in cats and dogs, and afterwards analyzed the blood, found urea in it—the characteristic element of urine. This principle was contained in greater quantity, the longer the period that had elapsed after the operation; whilst it could not be detected in the blood, when the kidneys were present. The experiment was soon afterwards repeated by MM. Vauquelin and Ségalas[1] with the same results. The latter introduced urea into the veins of an animal whose kidneys were untouched; he was unable to detect the principle in the blood; but the urinary secretion was largely augmented after the injection; whence he concludes, that urea is an excellent diuretic. Subsequently, MM. Gmelin and Tiedemann, in association with M. Mitscherlich,[2] arrived, experimentally, at the same conclusions as MM. Prévost and Dumas. The existence of urea in the fluid ejected from the stomach of the animal was rendered probable, but there were no traces of it in the fæces or bile. The animal died the day after the extirpation of the second kidney. They were totally unable to detect either urea or sugar of milk in the healthy blood of the cow.

These circumstances would favour the idea, that certain of the secretions may be formed in the blood, and may simply require the intervention of a secreting organ to separate them;[3] but the mode in which such separation is effected is entirely inexplicable under the doctrine of simple mechanical filtration or transudation. It is unlike any physical process that can be imagined. The doctrine of filtration and transudation can apply only to those exhalations in which the humour has undergone no apparent change; and it is obviously impossible to specify these, in the imperfect state of our means of analysis. In the ordinary aqueous secretions, simple transudation may embrace the whole process; and, therefore, it is unnecessary to have recourse to any other explanation; especially after the experiments instituted by M. Magendie, supported by pathological observations in which there has been partial œdema of the legs, accompanied by more or less complete obliteration of the veins of the infiltrated part,—the vessels being obstructed by fibrinous coagula, or compressed by circumjacent tumours. Thus, ascites or dropsy of the peritoneum may be occasioned by obstruction of the portal circulation in the liver, and in this way we may account for the frequency with which we find a union of hydropic and hepatic affections in the same individual. The like pathological doctrine, founded on direct observation, has been extended to phlegmasia dolens or swelled leg; an affection occurring in the puerperal state, and often found connected with obstruction in the great veins that convey the blood back from the lower extremity. It may not, consequently, be wide of the truth—if not wholly accurate—to consider certain of the secretions, with Dr. Billing,[4] to be "vital transudations from the capillaries into the excretory ducts of the glands, by pores invisible to our senses, even when aided by the most perfect optical instruments."

[1] Magendie, Précis, &c., ii. 478.

[2] Tiedemann and Treviranus. Zeitschrift für Physiol., B. v. Heft i.; cited in Brit. and Foreign Med. Review, p. 592. for April. 1836.

[3] Dr. W. Philip. in Lond. Med. Gazette for March 25th, 1837, p. 952.

[4] First Principles of Medicine, Amer. edit., p. 55, Philad., 1842; 2d Amer. edit., Philad., 1851.

The generality of physiologists have regarded the more complex secretions—the follicular and glandular—as the results of chemical action; and under the view, that these secretions do not exist ready formed in the blood, and that their elements alone are contained in that fluid, it is impossible not to admit that chemical agency must be exerted. In support of the chemical hypothesis, which has appeared under various forms,—some, as Keill,[1] presuming that the secretions are formed in the blood, before they arrive at the place appointed for secretion; others, that the change is effected in the glands themselves, —the fact of the formation of a number of substances from a very few elements, provided these be united in different proportions, has been urged. Take, for example, the elementary bodies, oxygen and nitrogen. These, in one proportion, form atmospheric air; in another, nitrous oxide; in another, nitric oxide; in a fourth, hyponitrous acid; in a fifth, nitrous acid; in a sixth, nitric acid, &c., compounds which differ as much as the various secretions differ from each other and from the blood. Many of the compounds of organization likewise exhibit, by their elementary constitution, that but a slight change is necessary, in order that they may be converted into each other. Dr. Prout[2] has exhibited the close alliance between three substances—urea, lithic acid, and sugar,—and has shown how they may be converted into each other, by the addition or subtraction of single elements of their constituents. Urea is composed of two atoms of hydrogen, and one of carbon, oxygen, and nitrogen respectively; by removing one of the atoms of hydrogen and the atom of nitrogen, it is converted into sugar; by adding to it an additional atom of carbon, into lithic or uric acid. Dr. Bostock,[3]—who is disposed to push the application of chemistry to the explanation of the functions as far as possible,—to aid us in conceiving how a variety of substances may be produced from a single compound, by the intervention of physical causes alone, supposes the case of a quantity of materials adapted for the vinous fermentation being allowed to flow from a reservoir through tubes of various diameters, and with various degrees of velocity. "If we were to draw off portions of this fluid in different parts of its course, or from tubes, which differed in their capacity, we should, in the first instance, obtain a portion of unfermented syrup; in the next, we should have a fluid in a state of incipient fermentation; in a third, the complete vinous liquor; while, in a fourth, we might have acetous acid." Any explanation, however, founded upon this loose analogy, is manifestly too physical. Dr. Bostock admits this, for he subsequently remarks, that "if we adopt the chemical theory of secretion, we must conceive of it as originating in the vital action of the vessels, which enables them to transmit the blood, or certain parts of it, to the various organs or structures of the body, where it is subjected to the action of those reagents which are necessary to the production of these changes." The admission of such vital agency, in some shape, is indispensable.

Attempts have been made to establish secretion as a nervous action,

[1] Tentamina Medico-Physica, iv.; and Haller, Element. Physiol., &c., lib. vii. sect. 3.

[2] Medico-Chirurg. Transact., viii. 540.

[3] Physiol., 3d edit., p. 519, Lond., 1836.

and numerous arguments and experiments have been brought forward in support of the position. That many of the secretions are affected by the condition of the mind is known to all. The act of crying, in evidence of joy or sorrow; the augmented secretion of the salivary glands at the sight of pleasant food; of the kidney during fear or anxiety; and the experimental confirmation, by Mr. Hunter, of the truth of the common assertion—that the she-ass gives milk no longer than the impression of the foal is on her mind,—the skin of the foal, thrown over the back of another, and frequently brought near her, being sufficient to renew the secretion,—sufficiently indicate, that the organs of secretion can be influenced through the nervous system in the same manner as the functions of nutrition and calorification.[1]

The discovery of galvanism naturally suggested it as an important agent in the process,—or rather that the nervous fluid strongly resembles the galvanic. This conjecture seems to have been first hazarded by Berzelius, and Sir Everard Home;[2] and, about the same time, an experiment was made by Dr. Wollaston,[3] which, he conceived, threw light on the process. He took a glass tube, two inches high, and three-quarters of an inch in diameter; and closed it at one extremity with a piece of bladder. He then poured into the tube a little water, containing $\frac{1}{240}$th of its weight of chloride of sodium, moistened the bladder on the outside, and placed it upon a piece of silver. On curving a zinc wire so that one of its extremities touched the piece of metal, and the other dipped into the liquid to the depth of an inch, the outer surface of the bladder immediately indicated the presence of pure soda; so that, under this feeble electric influence, the chloride of sodium was decomposed, and the oxide of sodium—soda—passed through the bladder. M. Fodéra[4] performed a similar experiment, and found, that whilst ordinary transudation frequently required an hour before it was evidenced, it was instantaneously exhibited under the galvanic influence. On putting a solution of cyanuret of potassium into the bladder of a rabbit, forming a communication with the solution by means of a copper wire; and placing on the outside a cloth soaked in a solution of sulphate of iron, to which an iron wire was attached; he found, by bringing these wires into communication with the galvanic pile, that the bladder or the cloth was suddenly coloured blue, according as the galvanic current set from without to within, or from within to without;—that is, according as the iron wire was made to communicate with the positive pole, and the copper wire with the negative, or conversely. But it is not necessary, that there should be communication with the galvanic pile. If an animal membrane, as a bladder, containing iron filings, be immersed in a solution of sulphate of copper, the sulphuric acid will penetrate the membrane to reach the iron, with which it forms a sulphate, and the metallic copper will

[1] For examples of the same kind, see Fletcher's Rudiments of Physiology, part ii. *b*, p. 10, Edinb., 1836; Burdach, Physiologie, u. s. w., § 522; Dr. A. Combe, on Infancy, Amer. edit., chap. v., Philad., 1840; and Carpenter, Principles of Human Physiology, Amer. edit., by Dr. F. G. Smith, p. 740, Philad., 1855.

[2] Lectures on Comp. Anat., iii. 16, London, 1816; and v. 154, London, 1828.

[3] Philosoph. Mag., xxxiii. 438.

[4] Magendie's Journal de Physiologie, iii. 35; and Recherches, &c., sur l'Absorption et l'Exhalation, Paris, 1824.

be deposited on the lower surface of the membrane; the animal membrane, in such case, offering no obstacle to the action of the ordinary chemical affinities.

With some of the chemical physiologists, there has been a disposition to resolve secretion into a mere play of electric affinities. Thus, M. Donné[1] affirms, that from the whole cutaneous surface an acid humour is secreted, whilst the digestive tube, except in the stomach, secretes an alkaline mucus: hence, he infers, that the external *acid*, and the internal *alkaline* membranes of the human body, represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer. On placing one of the conductors of the instrument in contact with the mucous membrane of the mouth, and the other with the skin, the magnetic needle deviated fifteen, twenty, and even thirty degrees, according to its sensibility; and its direction indicated, that the mucous or alkaline membrane took negative, and the cutaneous membrane, positive electricity. He further asserts, that, between the *acid* stomach and the *alkaline* liver, extremely powerful electrical currents are formed. These experiments do not, however, aid us materially in our solution of the phenomena of secretion. They exhibit merely electrical phenomena dependent upon difference of chemical composition. This is, indeed, corroborated by the experiments of M. Donné himself on the secretions of vegetables. He observed electrical phenomena of the same kind in them; but, he says, electrical currents in vegetables are not produced by the acid or alkaline conditions of the parts as in animals, the juice of fruits being always more or less acid. Experiments of M. Biot, however, show, that the juices, which arrive by the pedicle, are modified in some part of the fruit, and M. Donné thinks it is perhaps to this difference in the chemical composition of the juices of the two extremities, that the electrical phenomena are to be attributed.

The effects of the section of the pneumogastric nerves on the functions of digestion and respiration have been given elsewhere, at some length. It was then stated, that when digestion was suspended by their division, Dr. Wilson Philip[2] was led to ascribe it to the secretion of the gastric juice having been arrested; an opinion, which Sir B. Brodie had been induced to form previously, from the results of experiments, which showed that the secretion of urine is suspended by the removal or destruction of the brain; and that when an animal is destroyed by arsenic, after the division of the pneumogastric nerves, all the usual symptoms are produced, except the peculiar secretion from the stomach. Sir B. Brodie did not draw the conclusion, that the nervous influence is absolutely necessary to secretion, but that it is a step in the process; and the experiments of M. Magendie[3] on the effect of division of the nerve of the fifth pair on the nutritive secretion of the cornea, confirm the position. We have, indeed, numerous evidences, that the nervous system cannot be indispensable to secretion. In all animals, this power must exist; yet there are some in which no nervous system is apparent. Dr. Bostock[4] has given references to cases of monstrous or deformed

[1] Annales de Chimie, &c., lvii. 400; and Journal Hebdomad., Fév., 1834.
[2] London Medical Gazette, March 18 and March 25, 1837.
[3] Précis, &c., ii. 489.
[4] Physiology, edit. cit., p. 525, Lond., 1836.

fœtuses, born with many of their organs fully developed, yet in which there was apparently no nervous system. It may be said, however, that, in all these cases, a rudimental nervous system may and must have existed; but setting aside the case of animals, secretion is equally effected in the vegetable, in which there is no nervous system; yet the function is accomplished as perfectly, and perhaps in as multiple a manner, as in animals. It is manifest, therefore, that this is one of the vital actions occurring in the very tissue of organs, of which we have no more knowledge than we have of the nutritive actions in general. All that we know is, that in special organs various humours are secreted from the blood, some of which can be detected in that fluid; others not.

The doctrine of developement by cells was an important step in this inquiry. It has been elsewhere shown how cells are considered to effect the work of absorption; and secretion is probably accomplished in a similar manner. It is essentially a function of nucleated cells,—such cells possessing a peculiar organic power by virtue of which they can draw into their interior certain kinds of materials, varying according to the nature of the fluid they are destined to secrete.[1] Some cells have merely to separate certain ingredients from the surrounding medium; others have to elaborate within themselves matters that do not exist as such in the nutritive medium. Although secreting cells thus differ in the nature of the fluid which they secrete, their structure seems to be nearly the same in all cases,—each consisting, like other primitive cells, of a nucleus, cell-wall, and cavity. The nucleus appears to be both the reproductive organ by which new cells are generated, and the agent for separating and preparing the secreted material. The cell-cavity seems chiefly destined to contain the secreted fluid until ready to be discharged; at which time the cell, then matured, bursts and discharges its contents into the inter-cellular space on which it is situate, or upon a free surface, as the case may be.

The mode of secretion in glands, of which Professor Goodsir takes the testicle of the *squalus cornubicus* as a type, appeared to him to be as follows. Around the extremities of the minute ducts of the glands are developed acini or primary nucleated cells, each of which, as it increases in size, has generated, within it, secondary cells—the product of its nucleus. The cavity of the parent cell does not communicate with the duct on which it is situate until its contents are fully matured, at which time the cell-wall bursts or dissolves away, and its contents are discharged into the duct. From this constant succession of growth and solution of cells it results, that the whole parenchyma of a gland is continually passing through stages of developement, maturity, and atrophy,—the rapidity of the process being in proportion to the activity of the secretion. There seems, consequently, in this view of the subject, to be no essential difference between the process of secretion, and the growth of a gland: the same cells are the agents by which both are effected. The parenchyma of glands is chiefly made up of a mass of cells in all stages of developement: as these cells individually increase in size, and so constitute their own growth as well as that of the common glandular mass, they are at the same time elaborating

[1] Professor Goodsir, Transactions of the Royal Society of Edinburgh, 1842; and Anatomical and Pathological Observations, Edinb., 1845.

within themselves the material of secretion, which, when matured, they discharge by dissolving away. There are numerous germinal spots or centres in a gland, from which acini or primary cells are developed. The true fluid of secretion, in Mr. Goodsir's opinion, is not the product of the parent cell of the acinus, but of its included mass of secondary cells, which themselves become primary secreting cells, and form the material of secretion in their cavities. In some cases, these secondary cells pass out entire from the parent cell, constituting a form of secretion in which the cells possess the power of becoming more fully developed after being discharged and cast into the duct or cavity of the gland. He considers growth and secretion to be identical—the same process under different circumstances,—a view which had indeed been already embraced by others, and which ought to be universal. It must be recollected, that bloodvessels, like absorbents, are shut sacs; and, therefore, the materials for nutrition and secretion must pass either through them in the manner suggested by Mr. Goodsir, or by transudation. Transudation, however, would seem to be mainly, if not wholly, applicable to tenuous fluids only; whilst every solid in the body must be nourished by materials obtained from the blood. The agency of cells in nutrition and secretion may, therefore, be regarded as established. Mr. Addison[1] has suggested, that these cells are not developed in the organs of nutrition and secretion at the expense of materials supplied by the blood; that they are neither more nor less than the colourless corpuscles of the blood, which elaborate those products whilst still floating in its current, and then escape from the vessels. It is not easy, however, to comprehend, that corpuscles, apparently identical, should exist in the blood charged with the different properties of separating bile, urine, saliva, &c., from the fluid; or that they could escape through the parietes of the containing bloodvessels, and then penetrate the parietes of the excretory ducts to take their place—it has been supposed—as epithelium cells on the lining membrane of these outlets. Moreover, as has been shown elsewhere, there is reason to believe, that the office of the white corpuscles of the blood is of a different character.[2]

In cases of vicarious secretion, we have the singular phenomenon of organs assuming an action for which they were not destined. If the secretion from the kidney, for example, be arrested, urine is occasionally found in the ventricles of the brain, and, at other times, a urinous fluid has been discharged by vomiting or by cutaneous transpiration: the secreting cells of those parts must, consequently, have assumed the functions of the kidney, and to this they were excited by the presence of urea, or the elements of the urinary secretion in the blood,—a fact, which exhibits the important influence that the condition of the blood must exert on the secretions, and, indeed, on nutrition in general.[3] It is thus that many of our remedial agents, alkalies,—the preparations of iodine, &c.,—produce their effects. They first enter the mass of blood,

[1] The Actual Process of Nutrition on the Living Structure demonstrated by the Microscope, &c., Lond., 1844.

[2] See p. 364 of this volume.

[3] An interesting case of vicarious secretion of milk has been recorded in Bulletino delle Scienze Mediche, April, 1839; cited in Brit. and For. Med. Rev. for Jan. 1840; and another by Dr. S. W. Mitchell, in Amer. Journ. of the Med. Sciences for July, 1855, which will be noticed under Lactation.

and, by circulating in the capillary system, induce a modification of the function of nutrition. There are other cases, again, in which the condition of the blood being natural, the cells of nutrition may assume morbid action. Of this we have examples in the ossification of organs, which, in the healthy condition, have no bony constituent; in the deposition of fat in cases of diseased ovaria; and in the altered secretions produced by any source of irritation in a secreting organ.[1]

In describing the physiology of the different secretions, one of three arrangements has usually been adopted; either according to the nature of the secreting organ, the function of the secreted fluid, or its chemical character. The first of these has been followed by MM. Bichat and Magendie,[2] who have adopted a division into *exhaled*, *follicular*, and *glandular* secretions. It is the one followed by M. Lepelletier, except that he substitutes the term *perspiratory* for *exhaled*. According to the second, embraced by MM. Boyer,[3] Sabatier,[4] and Adelon,[5] they are divided into *recrementitial*, or such as are taken up by internal absorption and re-enter the circulation; and *excrementitial*, or such as are evacuated from the body, and constitute the excretions. Some physiologists add a third,—the *recremento-excrementitial*,—in which a part of the humour is absorbed and the remainder ejected. Lastly, the division according to chemical character has been followed, with more or less modification, by Plenck,[6] Richerand,[7] Blumenbach,[8] Young,[9] and Bostock;[10] the last of whom has eight classes; the *aqueous*, *albuminous*, *mucous*, *gelatinous*, *fibrinous*, *oleaginous*, *resinous*, and *saline*. To all of these classifications cogent objections might be made. The one we shall follow is the anatomical,—not because it is the most perfect, but because it is the course that has been usually adopted throughout this work. Defective, too, as it is, it will enable us to take a survey of every one of the numerous secretions classified in the following

TABLE OF THE SECRETIONS.

I. Exhalations or Simple Secretions.	A. Internal.	1. Areolar.	
		2. Serous.	General and vascular.
		3. Synovial.	
		4. Adipous.	Fat. Marrow.
		5. Pigmental.	
		6. Capsular.	
	B. External.	1. Dermic.	Skin. Mucous membranes.
		2. Menstrual.	
	C. Internal and external.	Gaseous.	

[1] See Dr. W. B. Carpenter, art. Secretion, in Cyclop. of Anat. and Physiol., iv. 439, Lond., 1852.

[2] Précis de Physiologie, 2de édit., ii. 243, Paris, 1825.

[3] Anatomie, 2de édit., i. 8, Paris, 1803. [4] Traité Complet d'Anatomie, Paris, 1791.

[5] Physiologie de l'Homme, edit. cit., iii. 438.

[6] The Chemico-Physiological Doctrine of the Fluids, &c., translated by Dr. Hooper, Lond., 1797.

[7] Élémens de Physiologie, 13ème édit., chap. vi., Bruxelles, 1837.

[8] Physiology, by Elliotson, 4th edit., Lond., 1828.

[9] Introduction to Medical Literature, p. 104, Lond., 1813.

[10] Physiology, 3d edit., p. 48, Lond., 1836.

II. Follicular Secretions.	1. Of mucous membranes.	Gastro-pulmonary, genito-urinary, &c.
	2. Of the skin.	
	a. Sebaceous.	
	b. Meibomian.	
	c. Ceruminous.	
	d. Preputial.	
	e. Odoriferous.	
	3. Of the ovaries.	
III. Glandular Secretions.	1. Of the skin.	
	2. Of the lachrymal gland.	
	3. Of the salivary glands.	
	4. Of the pancreas.	
	5. Of the liver.	
	6. Of the kidneys.	
	7. Of the testes.	
	8. Of the mammæ.	

I. EXHALATIONS OR SIMPLE SECRETIONS.

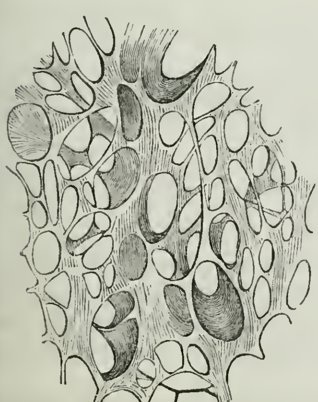
All the exhalations take place into the areolæ and internal cavities of the body,—or from the skin and mucous membranes;—hence such division into *internal* and *external.* The former are *recrementitial*, the latter *recremento-excrementitial.* To the class of *internal exhalations* belong: 1. The areolar exhalation. 2. The serous exhalation. 3. The synovial exhalation. 4. The adipous exhalation. 5. The pigmental exhalation. 6. The exhalation of the areolar capsules. To the class of *external exhalations* belong: 1. The exhalation of the mucous membranes. 2. The menstrual exhalation. The gaseous exhalations may be either external or internal.

A. INTERNAL EXHALATIONS.

1. *Areolar Exhalation.*

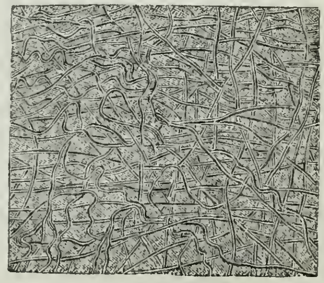
A brief view of the nature of the primary *areolar*, *cellular*, *fibro-cellular*, or *connective* membrane or tissue was given in an early part of this work. As we observe it, it is not properly cellular, but is com-

Fig. 140.



Portion of Areolar Tissue inflated and dried, showing the general character of its larger meshes; magnified twenty diameters.

Fig. 141.



Arrangement of Fibres in Areolar Tissue.—Magnified 135 diameters.

posed of a network of fibres, and lamellæ formed by the adhesion of fibres laid side by side; and these interwoven so as to leave numerous interstices and areolæ amongst them, which have a tolerably free communication with each other.[1]

Two kinds of fibrous tissue—the *white* and the *yellow*—may be detected in it,—the *white* presenting itself in the form of inelastic bands, the largest $\frac{1}{500}$th of an inch in breadth, somewhat wavy in their direction, marked longitudinally by numerous streaks, and being entirely resolved into gelatin by long boiling; and the *yellow* existing in the form of long, single, elastic, branched filaments, with a dark decided border, and disposed to curl when not put upon the stretch. These interlace with the others, but seem to have no continuity of substance with them. They are, for the most part, between the $\frac{1}{5000}$th and $\frac{1}{10000}$th of an inch in thickness; but are often met with both larger and smaller. It is not much changed by prolonged boiling; and appears to be mainly albuminous in its character.

The interstices in the areolar membrane, wherever existing, are kept moist by a serous fluid, analogous to that exhaled from serous membranes, and which appears to have the same uses,—that of facilitating the motion of the lamellæ, or fibres on each other, and, consequently,

Fig. 142.

White Fibrous Tissue, from Ligament.—Magnified 65 diameters.

Fig. 143.

Yellow Fibrous Tissue, from Ligamentum Nuchæ of Calf.—Magnified 65 diameters.

of the organs between which the areolar tissue is placed. When this secretion collects, from the causes mentioned in the last section, the disease called *œdema* or *anasarca* is induced.

2. *Serous Exhalation—General and Vascular.*

a. General.

This is the fluid secreted by the serous membranes that line the various cavities of the body;—as the pleura, pericardium, peritoneum, arachnoid coat of the brain, tunica vaginalis testis, and the lining membrane of the vessels. Rudolphi[2] asserts, that serous membranes

[1] For the histology of the areolar and serous membranes, see Todd and Bowman, Physiological Anatomy and Physiology of Man, London. 1842; and Dr. Brinton, art. Serous and Synovial Membranes, Pt. xxxiv. p. 512, London, Jan., 1849.

[2] Grundriss der Physiologie, § 113, Berlin, 1821.

are incapable of inflammation, are not vascular, and do not secrete; and that the secretions of shut sacs take place from the subjacent parts, and transude through the serous membrane, which, consequently, in his view, is a kind of cuticle. In a physiological consideration, it is not of moment whether they resemble the cuticle or not; and anatomically the question only concerns the layer that covers the surface.

Serous membranes, as elsewhere remarked, form shut sacs, and invest viscera, whose free surfaces come in contact, or which lie in cavities unattached to surrounding parts. To the law, that they form close or shut sacs, there is but one exception in the human subject; in the opening of the Fallopian tubes into the cavity of the abdomen.

They are constituted of fibro-areolar tissue so interwoven as to constitute a membrane,—the free surface covered with a layer of flattened cells forming, in most cases, a *tessellated epithelium.* Between the epithelium and subserous areolar tissue is the *primary* or *basement membrane.*[1] The basement membrane and epithelium are concerned in the secretion of the fluid by which the free surface of the membrane is moistened. The general arrangement of serous membranes has been well described by Professor Goodsir.[2] A portion of the human pleura or peritoneum, according to him, consists, from its free surface inwards, of a single layer of nucleated scales; of a germinal membrane, and of a subserous areolar texture intermixed with occasional elastic fibres. The bloodvessels of the serous membrane ramify in the areolar texture. The germinal membrane seldom shows the lines of junction of its component flattened cells. These appear elongated in the form of ribands,—their nuclei or the germinal spots of the membrane being elongated, expanded at one extremity, pointed at the other, and somewhat bent upon themselves; they are bright and crystalline, and may or may not contain smaller cells in their interior. If these germinal centres be the sources of all the scales of the superficial layer, each centre being the source of the scales of its own compartment, then the matter necessary for the formation of these during their developement must pass, he conceives, from the capillary vessels to each of the centres, acted on by forces whose centres of action are the germinal spots;—each of the scales, after being detached from its parent centre, deriving its nourishment by its own inherent powers.

From these membranes a fluid is exhaled, which is of an albuminous character, resembling greatly the serum of the blood, except in containing less albumen. M. Donné[3] says it is always alkaline in the healthy state. This is owing to the presence of carbonate or albuminate of soda. It contains 7 or 8 per cent. of albumen, and salts. In health, this fluid never accumulates in the cavities,—the absorbents taking it up in proportion as it is deposited; but if, from any cause, the exhalants should pour out a larger quantity than usual, whilst the absorbents are not proportionably excited, accumulation may take place; or the same effect may ensue if the exhalants pour out no more

[1] Bowman, art. Mucous Membrane, Cyclopædia of Anatomy and Physiology, p. 484, April, 1842.

[2] Anatomical and Pathological Observations, Edinb., 1845.

[3] Journal Hebdomad., Février, 1834.

than their usual quantity, whilst the absorbents do not possess their due activity. Under either circumstance, we have an accumulation—a dropsy. The exhaled fluid probably transudes through the parietes of the arteries, and re-enters the circulation by imbibition through the coats of the veins. If we kill an animal and open it immediately afterwards, this exhalation appears in the form of a halitus or vapour, and the fluid is seen lubricating the free surface of the membrane. This, indeed, appears to be its principal office; by which it favours the motion of the organs upon each other.

The serous exhalations probably differ somewhat in each cavity, or according to the precise structure of the membrane. The difference between the chemical character of the fluid of the dropsy of different cavities would lead to this belief. As a general rule, according to Dr. Bostock,[1] the fluid from the cavity of the abdomen contains the greatest proportion of albumen, and that from the brain the least; but many exceptions occur to this.

b. Vascular.

A fluid is exhaled from the inner or serous coat of the arterial, venous, and lymphatic vessels. It probably does not differ much from the fluid of serous membranes in general; and its use, doubtless, is to lubricate the interior of the vessel, and prevent adhesion between it and the fluid circulating within it.

3. *Synovial Exhalation.*

Within the articular capsules, and bursæ mucosæ,—which are described under Muscular Motion,—a fluid is secreted, which is spread over the articular surfaces of bones, and facilitates their movements. Dr. Clopton Havers[2] considered this fluid to be secreted by *synovial glands*,—for such he conceived the reddish cellular masses to be, that are found in certain articulations. Haller[3] strangely regarded the synovia as the marrow, which had transuded through the spongy extremities of the bones; but, since the time of Bichat, every anatomist and physiologist has ascribed it to the exhalant action of the synovial membrane,—which strongly resembles the serous membranes in form, structure, and functions,—whose folds constitute the projections that Havers mistook for glands. The opinion of Havers has, however, been confirmed by Mr. Rainey.[4] It had been believed by many, that the folds of synovial membrane, which form fringes, contain merely globules of fat, and are only inservient to the mechanical office of filling up spaces that would otherwise be left vacant during the movements of the joints. By a careful examination of their structure, with the aid of the microscope, Mr. Rainey found a peculiar arrangement of vessels not at all resembling those that secrete fat, and an epithelium of remarkable form and disposition, and characteristic of organs whose function it is to effect a special secretion. These

[1] Op. citat., p. 485.
[2] De Ossibus, serm. iv. c. 1; and Osteologia Nova, London, 1691.
[3] Element. Physiol., iv. 11.
[4] Proceedings of the Royal Society of London, No. 65, 1847.

fringes he traced not only in the joints but in the sheaths of tendons, and in the bursæ—wherever, indeed, synovia is secreted. When well injected they are seen under the microscope to consist of a convolution of bloodvessels and an investing epithelium, which, besides enclosing separately each packet of convoluted vessels, sends off from each tubular sheath secondary processes of various shapes into which no bloodvessels enter. The lamina itself forming these folds and processes consists of a very thin membrane studded with flattish oval cells, a little larger than blood corpuscles, but destitute of nucleus or nucleolus,—presenting none of the characters of tessellated epithelium, but corresponding more to what Mr. Goodsir has termed "germinal membrane." The proper office of this structure is to secrete synovia.

The synovial membrane exists in all the movable articulations, and in the channels and sheaths in which the tendons play. The articular capsules are shut sacs; and the generality of anatomists consider that the membranes are reflected over the incrusting cartilages. M. Magendie, however, affirms, that he has several times satisfied himself, that they do not pass beyond the circumference of the cartilages. From the inner surface of these membranes the synovia is exhaled in the same manner as in other serous cavities.

M. Margueron[1] analyzed synovia obtained from a posterior extremity of the ox, and found it consist of modified albumen presenting the colour, smell, taste, and elasticity of vegetable gluten, fibrinous matter, 11·86; albumen, 4·52; chloride of sodium, 1·75; carbonate of soda, 0·71; phosphate of lime, 0·70; and water, 80·46. M. Donné[2] says it is always alkaline in health; but in certain diseases sometimes becomes acid. The synovia of a stall fed ox was found by Frerichs[3] to consist of

Water,	969·90
Solid constituents,	30·10
Mucous matter with epithelium,	2·40
Fat,	0·62
Albumen and extractive matter,	15·76
Salts,	11·32

That of an ox, which had been pasture-fed all the summer, contained

Water,	948·54
Solid constituents,	51·46
Mucous matter and epithelium,	5·60
Fat,	0·76
Albumen and extractive matter,	35·12
Salts,	9·98

4. *Adipous Exhalation.*

a. Fat.

Considerable diversity of opinion has prevailed regarding the precise organ for the secretion of fat. Haller supposed, that the substance

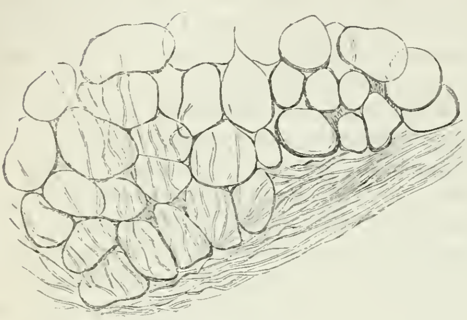
[1] Annales de Chimie, xiv. 123; and art. Synovie, Dict. des Sciences Médicales, liv. 125, Paris, 1821.

[2] Journal Hebdomad., Février, 1834.

[3] Art. Synovia, in Wagner's Handwörterbuch der Physiologie, 18te Lieferung, s. 467, Braunschweig, 1848.

exists ready formed in the blood, and simply transudes through the pores of the arteries; and Chevreul and others have given confirmation to the opinion, by the circumstance of their having met with fatty matter in that fluid. Anatomists have, likewise, been divided upon the subject of the precise tissue into which the fat is deposited; some believing it to be the ordinary areolar tissue, into which it is dropped by the agency of appropriate vessels; others, as Malpighi[1] and Dr. William Hunter,[2] believing in the existence of a peculiar adipous tissue, consisting, according to M. Béclard,[3] of small bursæ or membranous vesicles, which enclose the fat, and are found in the areolæ of the tissue. These vesicles are said to vary greatly in size: generally, they are round and globular; and, in certain subjects, receive very apparent vessels. They form so many small sacs without apertures, in the interior of which are filaments arranged like septa. In fatty subjects, these adipous vesicles are very perceptible, being attached to the areolar tissue and neighbouring parts by a vascular pedicle.

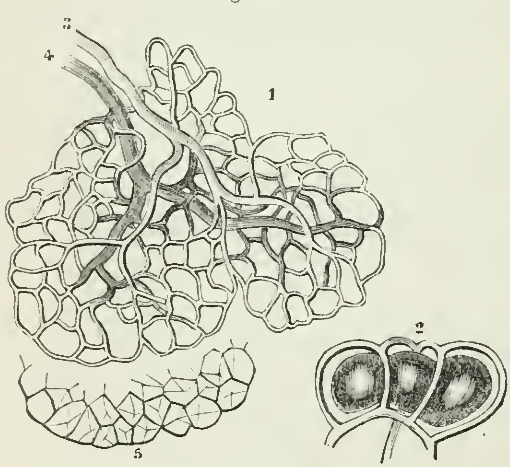
Fig. 144.



A small cluster of Fat-Cells magnified 150 diameters.

The fat originates from fat-cells, which are usually of a spherical or spheroidal shape, but sometimes, when closely pressed together without the intervention of any intercellular substance, they become polyhedral. The adipous tissue is a membrane of extreme tenuity, which forms the vesicle that includes the fat. The membrane is homogeneous and transparent, about the $\frac{1}{20000}$th of an inch thick,

Fig. 145.



Bloodvessels of Fat Vesicles.

1. Minute flattened fat lobule, in which the vessels only are represented. 3. Terminal artery. 4. Primitive vein. 5. Fat vesicle, of one border of the lobule, separately represented. Magnified 100 diameters.—2. *Plan* of the arrangement of capillaries on the exterior of the vesicles, more highly magnified.

[1] De Omento, Pinguedine, et Adiposis Ductibus, in Oper., London, 1687.

[2] Medical Observations and Inquiries, vol. ii., London, 1777.

[3] Art. Adipeux, in Dictionnaire de Médecine, tom. i.; and Elements of General Anatomy, translated by Togno, p. 128, Philad., 1830.

and is moistened by a watery fluid, for which it has a greater attraction than the fat it contains. Each vesicle is from the $\frac{1}{300}$th to the $\frac{1}{800}$th of an inch in diameter. When the fat vesicles exist in any number, their arrangement is generally lobular, with an investment of areolar tissue, which favours motion, and the distribution of the blood-vessels. These enter the interlobular clefts, ramify through their interior as a solid capillary network, occupy the angles formed by contiguous sides of the vesicles, and anastomose with one another at the points where these angles meet.

M. Raspail[1] affirms, that there is the most striking analogy between the nature of the adipous granules and that of the amylaceous grains. As in the case of fecula, each adipous granule is composed of at least one integument, and an enclosed substance, both of which are as slightly nitrogenized as fecula; and both fecula and fat are equally inservient to the nutrition of the organs of developement: whenever there is excess of life and activity, the fat is seen to disappear, and whenever there is rest, it accumulates in its reservoirs. If a portion of fat be examined, it is found to consist of an outer vesicle with strong membranous parietes, containing small adipous masses readily separable from each other, each invested with a similar, but slighter, vesicular membrane; and these, again, contain others still more minute, until ultimately we come to the vesicles that invest the adipous granules themselves. Each of these masses adheres, at some point of its surface, to the inner surface of the vesicle that encloses it, by a hilum in the same manner as the grain of fecula. All the vesicles, but especially the outermost and strongest, have a reddish vascular network on their surface, the vessels of which augment in size as they approach the part where the vesicle is adherent, and there open into one of the vessels of the larger vesicle that encloses them.

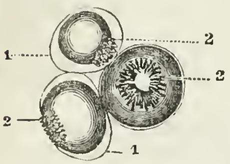
The arrangement of this tissue, as well as the quantity of fat, varies in different parts of the body. It is always found in the orbit, on the sole of the foot, and at the pulps of the fingers and toes. The subcutaneous areolar tissue, and that covering the heart, kidneys, &c., also generally contain it; but it is never met with in deposit in the eyelids, scrotum, or within the cranium.

Fat is exhaled by the secretory vessels in a fluid state; but after it is deposited, it becomes more or less solid. According to the researches of MM. Chevreul[2] and Braconnot, human fat is almost always of a yellow colour; inodorous, and composed of two portions;—the one fluid, and the other concrete, which are themselves composed, but in different proportions, of two immediate principles, to which the former chemist gave the names *elain* or *olein*, and *stearin*. Subsequently, the organic elements of fat were considered to be *stearin*, *margarin*, and *olein*; the two former, which are solid when separate, being dissolved in the latter at the ordinary temperature of the body. Chemistry has, however, shown, that the fat contained in the cells of the adipous tissue is composed of a base of a sweetish taste, thence termed *glycerin*, itself an oxide of glyceryl, with stearic, margaric, and oleic acids,—stearin being

[1] Chimie Organique, p. 183, Paris, 1833.
[2] Recherches Chimiques sur les Corps Gras, &c., Paris, 1823.

esteemed a bi-stearate of glycerin; and olein or elain an oleate of glycerin. These proximate principles are sometimes seen spontaneously separated within the human fat vesicle. The stearin collects in the form of a small star on the inner surface of the membrane, as in the marginal figure at 2, 2, 2, the elain occupying the remainder of the vesicle, except where there is an unusually small quantity of fat, when a little aqueous fluid is seen interposed between the elain and the cell-membrane.

Fig. 146.



Fat Vesicles from an Emaciated Subject.

1, 1. Cell-membrane. 2, 2, 2. Solid portion collected as a star-like mass, with the elain in connexion with it, but not filling the cell.

It is probable, that chemical analysis would exhibit the fat to vary in different parts of the body, as its sensible properties are different. Sir Everard Home,[1] on loose analogies and inconclusive arguments, has advanced the opinion, that it is more than probable, that fat is formed in the lower portion of the intestines; and thence is carried, through the medium of the circulating blood, to be deposited in almost every part of the body. "When there is a great demand for it, as in youth, for carrying on growth, it is laid immediately under the skin, or in the neighbourhood of the abdomen. When not likely to be wanted, as in old age, it is deposited in the interstices of muscular fibres, to make up in bulk for the wasting of these organs. M. de Blainville[2] held the opinion, that fat is derived from venous blood, and that it is exhaled through the coats of the vessels. This opinion he founds on the mode in which the fat is distributed in the omenta along the course of the veins; and he affirms, that he has seen it flow out of the jugular vein in a dead elephant. But this last fact, as M. Lepelletier[3] has judiciously remarked, proves nothing more than that fat—taken up by the absorbents from the vesicles in which it had been deposited by the exhalants—had been conveyed into the venous blood with other absorbed matters. It in no wise shows, that the venous blood is the pabulum of the secretion, or that the veins accomplish it.

The purposes served by the fat are both *general* and *local*. The great general use is, by some physiologists, conceived to be,—to serve as a provision in cases of wasting indisposition; when the digestive function is incapacitated for performing its due office, and emaciation is the consequence. In favour of this view, the rapidity with which fat disappears after slight abstinence has been urged, as well as the facts, connected with the torpidity of animals, which are always found to diminish in weight during this state. Professor Mangili, of Pavia, procured two marmots from the Alps, on the 1st of December. The larger weighed 25 Milanese ounces; the smaller only $22\frac{1}{8}$th; on the 3d of January, the larger had lost $\frac{3}{4}$ths of an ounce, and the smaller $\frac{1}{2}\frac{3}{4}$ths. On the 5th of February, the larger weighed only $22\frac{7}{8}$: the smaller 21. Dr. Monro kept a hedgehog from the month of November to the

[1] Lect. on Comp. Anat., i. 468, Lond., 1814, and vol. vi. Lond., 1828; and Philos. Transact., 1821, p. 34.
[2] De l'Organisation des Animaux, &c., Paris, 1825.
[3] Physiologie Médicale et Philosophique, ii. 496, Paris, 1832.

month of March following, which lost, in the meanwhile, a considerable portion of its weight. On the 25th of December, it weighed 13 ounces and 3 drachms; on the 6th of February, 11 ounces and 7 drachms; and on the 8th of March, 11 ounces and 3 drachms. The loss was 13 grains daily.[1]

The local uses of fat are chiefly of a physical character. On the sole of the foot it diminishes the effects of pressure, and serves the same office on the nates; in the orbit it forms a kind of cushion, on which the eyeball moves with facility; and when in certain limits it gives that rotundity to the frame, which we are accustomed to regard as beauty of form. Dr. Fletcher,[2] indeed, considers its principal use to be, to fill up interstices, and thus to give a pleasing contour to the body. In another place, it is observed, that fatty substances are bad conductors of caloric; and hence may tend to preserve the temperature of the body in cold seasons; a view which is favoured by the fact, that many of the Arctic animals are largely supplied with fat beneath the common integuments; and it has been affirmed, that fat people generally suffer less than lean from the cold of winter.

It is obviously impracticable to estimate accurately the total quantity of fat in the body. It has been supposed that, in an adult male of moderate size, it forms $\frac{1}{20}$th of the whole weight; but it is doubtful whether we ought to regard this as even an approximation,—the data being so inadequate. In some cases of polysarcia or obesity, the bulk of the body has been enormous. That of a girl is detailed, who weighed 256 pounds, when only four years old.[3] A girl, said to be only ten years old, called the "Ohio giantess," was exhibited in Philadelphia, in the year 1844, who was said to weigh 265 pounds; and in March, 1847, an Ohio girl, twelve years of age—perhaps the same—was exhibited, who weighed 330 pounds. The Lowell Advertiser, of September, 1844, states, that a coloured girl, aged fourteen, a native of Nassau, New York, died in that city, weighing 500 pounds. A man of the name of Bright, at Malden, England, weighed 728 pounds; and the celebrated Daniel Lambert, of Leicester, England, weighed 739 pounds a little before his death, which occurred in the fortieth year of his age.[4] The circumference of his body was three yards and four inches; and of his leg one yard and one inch. His coffin was six feet four inches long; four feet four inches wide; and two feet four inches deep. A Kentuckian, of the name of Pritchard, who exhibited himself in Cincinnati, in 1834, weighed five hundred and fifty pounds. The "Canadian giant,"—as he was called—whom Dr. Gross[5] saw in Philadelphia, in 1829, weighed six hundred and eighteen pounds. He was six feet four inches in height, and the circumference of each leg around the calf was nearly three feet. The deposition of fat was confined chiefly to the abdomen and lower limbs,—the thorax, shoulders, and arms being little larger than in other persons. The public Journals of this country[6] have recorded the death of a Mr. Cornelius, who

[1] Fleming, Philosophy of Zoology, ii. 59, Edinb., 1822.
[2] Rudiments of Physiology, part iii., by Dr. Lewins, p. 71, Edinb., 1837.
[3] Philos. Transact., No. 185.
[4] Good's Study of Medicine, Class vi. Ord. 1, Gen. 1, Sp. 1.
[5] Elements of Pathological Anatomy, 2d edit., p. 202, Philad., 1845.
[6] Philadelphia Public Ledger, October 4, 1841.

weighed 720 pounds; and in the year 1854, a woman was exhibited in Philadelphia, who was said to weigh 764 pounds; and another 800 pounds. Dr. Elliotson[1] says he saw a female child, but a year old, which weighed sixty pounds. She had begun to grow fat at the end of the third month.

In these cases, the specific gravity of the body may be much less than that of water. It is said, that some time ago there was a fat lighterman, on the river Thames, "who had fallen overboard repeatedly, without any farther inconvenience than that of a good ducking; since though he knew nothing whatever of the art of swimming, he always continued to flounder about like a firkin of butter, till he was picked up."[2]

In some of the varieties of the human family singular adipous deposits are met with. In the Bosjesman female vast masses of fat accumulate on the buttocks, which give them the most extravagant appearance. The projection of the posterior part of the body, in one subject, according to Sir John Barrow,[3] measured five inches and a half from a line touching the spine. "This protuberance," he remarks, "consisted of fat, and when the woman walked had the most ridiculous appearance imaginable, every step being accompanied with a quivering and tremulous motion, as if two masses of jelly were attached behind." The "Hottentot Venus," who had several projections, measured more than nineteen inches around the haunches; and the projection of the hips exceeded $6\frac{1}{3}$ inches. Dr. Somerville[4] found on dissection, that the size of the buttocks arose from a vast mass of fat, interposed between the integuments and muscles, which equalled four fingers' breadth in thickness. It is singular that, according to the statement of this female, which is corroborated by the testimony of Sir John Barrow, the deposition does not take place till the first pregnancy. Pallas[5] has described a variety of sheep—*ovis steatopyga* or "fat buttocked"—which is reared in immense flocks by the pastoral tribes of Asia. In it, a large mass of fat covers the nates and occupies the place of the tail. The protuberance is smooth beneath, and resembles a double hemisphere, when viewed behind,—the os coccygis or rump-bone being perceptible to the touch in the notch between the two. They consist merely of fat; and, when very large, shake in walking like the buttocks of the female Bosjesman. Mr. Lawrence[6] remarks, that there are herds of sheep in Persia, Syria, Palestine, and some parts of Africa, in which the tail is not wanting as in *ovis steatopyga*, but retains its usual length, and becomes loaded with fat.

According to Liebig,[7] the abnormous condition, which causes an undue deposition of fat in the animal body, depends on a disproportion between the quantity of carbon in the food, and that of the oxygen absorbed by the skin and lungs. In the normal condition, the

[1] Human Physiology, London, 1841, P. i. 331.

[2] Fletcher, Rudiments of Physiology, by Dr. Lewins, pt. 3, p. 71, Edinb., 1837.

[3] Travels into the interior of Southern Africa, p. 281, London, 1801.

[4] Medico-Chirurgical Transactions, vii. 157.

[5] Spicilegia Zoologica, fasc. xi. p. 63. Also, Erman, Travels in Siberia, Amer. edit., Philad., 1850.

[6] Lectures on Physiology, Zoology, &c., p. 427, London, 1819.

[7] Animal Chemistry, Webster's edit., p. 85, Cambridge, Mass., 1842.

quantity of carbon given out is exactly equal to that which is taken in the food, and the body experiences no increase of weight from the accumulation of substances containing much carbon and no nitrogen; but if the supply of highly carbonized food be increased, then the normal state can only be preserved by exercise and labour, through which the waste of the body is increased, and the supply of oxygen accumulated in the same proportion. The production of fat, Liebig maintains, is always a consequence of a deficient supply of oxygen; for oxygen is absolutely indispensable for the dissipation of the excess of carbon in the food. "This excess of carbon, deposited in the form of fat, is never seen in the Bedouin or in the Arab of the desert, who exhibits with pride to the traveller his lean, muscular, sinewy limbs, altogether free from fat; but in prisons and jails it appears as a puffiness in the inmates, fed, as they are, on a poor and scanty diet: it appears in the sedentary females of oriental countries; and is produced under the well-known conditions of fattening of domestic animals."

In accordance, too, with his views of animal temperature, already referred to, Liebig considers that in the formation of fat there is a new source of heat. The oxygen set free in the action is given out in combination with carbon and hydrogen; and whether this carbon and hydrogen proceed from the substance that yields the oxygen, or from other compounds, still there must have been generated by the formation of carbonic acid or water as much heat as if an equal weight of carbon or hydrogen had been burned in air or in oxygen gas.

Whether the view of Liebig be admitted or not, it is certain that the circumstances, which favour obesity, are absence of activity and excitement of all kinds; hence, for the purpose of fattening animals in rural economy, they are kept in entire darkness, to deprive them of the stimulus of light, and encourage sleep and muscular inactivity. Castration—by abolishing one kind of excitability—and the time of life at which the generative functions cease to be exerted, especially in the female, are favourable to the same result.

b. Marrow.

A fluid, essentially resembling fat, is found in the cavity of long bones, in the spongy tissue of short bones, and in the areolæ of bones of every kind. This is the *marrow—medulla ossium.* The secretory organ is the very delicate membrane, which is perceptible in the interior of the long bones, lining the medullary cavity, and sending prolongations into the compact substance, and others internally, which form septa and spaces for the reception of the marrow. The cells, thus formed, are distinct from each other. From the observations of Mr. Howship,[1] it would seem probable, that the oil of bones is deposited in longitudinal canals, that pass through the solid substance of the bone, and through which its vessels are transmitted. This *oil of bones* is the *marrow* of the compact structure, the latter term being generally restricted to the secretion when contained in the cavities of long bones; that which exists in the spongy substance being termed, by some writers, the *medullary juice.* The *medullary membrane*, called

[1] Medico-Chirurg. Trans., vii. 393.

also the *internal periosteum*, consists chiefly of bloodvessels ramifying on an extremely delicate areolar tissue, in which nerves may likewise be traced.

Marrow is seen in two forms, one yellow and the other red. The former which is found principally in the long bones, is a semifluid substance, and was examined by Berzelius as obtained from the humerus of an ox. He found it to consist of the following constituents:—pure adipous matter, 96; skins and bloodvessels, 1; albumen, gelatin, extractive, peculiar matter, and water, 3. The latter is found in the processes, and in flat and short bones; in the bodies of the vertebræ, basis cranii, sternum, &c. That of the diploe was examined by Berzelius, and found to contain 75.0 water, and 25·0 solid matters—as albumen, fibrin, extractive and salts.[1]

The marrow is one of the corporeal components, of whose use we can scarcely offer a plausible conjecture. It has been supposed to render the bones less brittle; but this is not correct, as those of the fœtus, which contain little or no marrow, are less so than those of the adult; whilst those of old persons, in whom the medullary cavity is large, are more brittle than those of the adult. It is possible that it may be placed in the cavities of bones,—which would otherwise be so many vacant spaces,—to serve the general purposes of fat, when required by the system. The other hypotheses that have been entertained on the subject are not deserving of notice.

5. *Pigmental Exhalation.*

The nature of the exhalation, which constitutes the colouring matter of the skin, will engage attention, when treating of the skin under the SENSE OF TOUCH. It is presumed to be exhaled by the vessels of the skin, and to be deposited beneath the cuticle, so as to communicate the colours that characterize the different races. Such is regarded as the secretory arrangement by most anatomists and physiologists; but M. Gaultier,[2] whose researches into the intimate constitution of the skin have gained him much celebrity, is of opinion, that it is furnished by the bulbs of the hair; and he assigns, as reasons for this belief, that the negro, in whom it is abundant, has short hair; that the female, whose hair is more beautiful and abundant than that of the male, has the fairest skin; and that when he applied blisters to the skin of the negro, he saw the colouring matter oozing from the bulbs and deposited at the surface of the rete mucosum. But the views of modern anatomists on the corpus mucosum are given elsewhere.

The composition of this pigment cannot be determined with precision, owing to its quantity being too small to admit of examination. Chlorine deprives it of its black hue, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with this gas, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned with its former intensity. The experi-

[1] Moser and Strahl, Handbuch der Physiologischen und Pathologischen Chemie, s. 334, Leipz., 1851.

[2] Recherches sur l'Organisation de la Peau de l'Homme, &c., Paris, 1809 and 1811.

ment was made with similar results on the fingers. Blumenbach[1] thought, that the mucous pigment was formed chiefly of carbon; and the notion has received favour with many.

The colour, according to Henle and others, is owing to pigment cells, of which the pigmentum nigrum of the eye is wholly composed. On the choroid coat they form a kind of pavement, and have somewhat of a polyhedral shape. In the human skin, they are scattered through the ordinary epidermic cells, and the colour of the skin is determined by that of their contents. Krause,[2] however, denies that the colour of the cuticle of the Ethiopian depends on pigment cells like those of the pigmentum nigrum. It is owing chiefly, he says, to the colour of the proper nuclei and cells of the epidermis. There are, indeed, some few pigment cells mingled with the proper cells of the middle and superficial layers of the epidermis; but they are distinguishable from those of the pigmentum nigrum by containing far fewer pigment granules, and by having always a dark, not a clear, nucleus. The colour depends especially on the dark or almost black-brown colour of the nuclei, whether free in the deep layers of epidermis or surrounded by cells. They have dark nucleoli and sharp outlines; appear only very obscurely granular, and cannot be broken into smaller pigment granules. The cells surrounding them may be seen in the deeper layers: they, also, are uniformly dark, although less so than the nuclei. In the middle and superficial layers, the nuclei, as long as they can be seen, are still dark; the cells are much paler, but brownish and darker than in the corresponding layers in uncoloured persons.

Pigment granules are amongst the most minute structures of the body, being not more than $\frac{1}{20000}$th of an inch in their largest diameter, and about one-fourth as much in thickness.

The uses of the pigment of the skin—as well as of that which lines the choroid coat of the eye, the posterior surface of the iris, and the ciliary processes—are detailed in other places.

6. *Capsular Exhalation.*

Under this term, M. Adelon[3] has included different recrementitial secretions effected within the organs of sense, or in parenchymatous structures,—as the aqueous, crystalline, and vitreous humours of the eye, and the liquor of Cotugno, all of which have already engaged attention; the exhalation of a kind of albuminous, reddish, or whitish fluid into the interior of the lymphatic ganglions, and into the organs, called by M. Chaussier, *glandiform ganglions*, and by M. Béclard, *sanguineous ganglions*;—namely, the thymus, thyroid, supra-renal capsules, and spleen. We know but little, however, of the fluids formed in these parts; and of their uses we are, in the main, ignorant.

B. EXTERNAL EXHALATIONS.

1. *Exhalations of the Skin and Mucous Membranes—Dermic.*

The mucous membranes, like the skin, which they so strongly resemble in their structure, functions, and diseases, exhale a similar tran-

[1] Instit. Physiol., § 274; and Elliotson's translation, 4th edit., Lond., 1828.

[2] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7te Lief., S. 108, Braunschweig, 1844.

[3] Physiologie de l'Homme, 2de edit., tom. iii. 483, Paris, 1829.

spiratory fluid. This has not been subjected to chemical examination. It is, indeed, almost impracticable to separate it from the follicular secretions of the same membrane; and from the extraneous substances almost always in contact with it. It is, probably, however, similar to the fluid of the cutaneous and pulmonary depurations, both in character and use.

The pulmonary transpiration, to which allusion has so often been made, bears a striking analogy to the cutaneous. Sir B. Brodie and M. Magendie, from the examination of cases of fistulous opening into the trachea, deny that it comes from the lungs, believing it to be formed by the moist mucous lining of the nose, throat, &c.; but this view has been disproved by Paoli and Regnoli, in the case of a young female, whose trachea had been opened, and in whom, at the temperature of 39° Fahr., watery vapour was distinctly expired through the canula. Mojon[1] strangely supposes the vapour of the breath to be a watery fluid secreted by the thyroid gland, and suspended in the respired air, its volatility being caused by the presence of caloric. At one time, it was universally believed to be owing to the combustion of the hydrogen and carbon given off from the lungs; but we have elsewhere shown, that no such combustion occurs there; and besides, the exhalation takes place when gases containing no oxygen are respired by animals. It is now almost universally admitted to be exhaled into the air-cells of the lungs from the pulmonary artery chiefly; but partly from the bronchial arteries distributed to the mucous membrane of the air-passages.[2] Much of the vapour, Dr. Prout conceives, is derived from the chyle in its passage through the lungs; and thus, he considers, the weak and delicate albumen of the chyle is converted into the strong and perfect albumen of the blood.

The air of expiration, according to Valentin[3] and Brunner appears saturated with it, so that, as they have remarked, the quantity of vapour exhaled may be estimated by subtracting the quantity contained in the atmospheric air expired from the quantity, which, at the same barometric pressure, would saturate the same atmospheric air at the temperature of 99·5°—the general temperature of the air of expiration. On the other hand, if the quantity of watery vapour in the expired air be estimated, the quantity of the air itself may thence be accurately determined—being as much as that quantity of watery vapour would saturate at the ascertained temperature and barometric pressure. It has not been established, however, that the expired air is saturated with moisture.[4]

Sundry interesting experiments have been made on this exhalation by Magendie, Milne Edwards, Breschet, and others. If water be injected into the pulmonary artery, it passes into the air-cells in myriads of almost imperceptible drops, and mixes with the air contained in them. M. Magendie[5] found, that its quantity might be augmented at

[1] Leggi Fisiologiche, &c., translated by Skene, p. 76, Lond., 1827.
[2] Sir B. Brodie, Philosophical Transactions for 1812, and Physiological Researches, p. 19, Lond., 1851.
[3] Lehrbuch der Physiologie des Menschen, i. 547, Braunschweig, 1844.
[4] Dr. John Reid, art. Respiration, Cyclop. of Anat. and Phys., pt. xxxii. p. 345, Lond., Aug., 1848.
[5] Précis, &c., ii. 346.

pleasure on living animals, by injecting distilled water, at a temperature approaching that of the body, into the venous system. He injected into the veins of a small dog a considerable amount of water. The animal was at first in a state of real plethora—the vessels being so much distended that it could scarcely move; but in a few minutes the respiration became manifestly hurried, and a large quantity of fluid was discharged from the mouth, the source of which appeared evidently to be the pulmonary transpiration greatly augmented.

But not only is the aqueous portion of the blood exhaled in this manner, experiment shows, that many substances introduced into the veins by absorption, or by direct injection, issue from the lungs. Weak alcohol, a solution of camphor, ether, and other odorous substances, when thrown into the cavity of the peritoneum or elsewhere, were found, by M. Magendie, to be speedily absorbed by the veins, and conveyed to the lungs, where they transuded into the bronchial cells, and were recognised in the expired air by their smell. Phosphorus, when injected, exhibited this transmission in a singular and evident manner. M. Magendie,[1] on the suggestion of M. Armand de Montgarny, "a young physician," he remarks, "of much merit," now no more, injected into the crural vein of a dog half an ounce of oil, in which phosphorus had been dissolved: scarcely had he finished the injection, before the animal sent through the nostrils clouds of a thick white vapour, which was phosphoric acid. When the experiment was made in the dark, these clouds were luminous. M. Tiedemann[2] injected a drachm of the expressed juice of garlic into a vein of the thigh of a middle-sized dog; in the space of three seconds the breath smelt strongly of garlic. When spirit of wine was injected, the exhaled vapour was recognised when the injection was scarcely over.

MM. Breschet and Milne Edwards[3] made several experiments for the purpose of discovering why the pulmonary transpiration expels so promptly the different gases and liquid substances received into the blood. Considering properly, that exhalation differs only from absorption in taking place in an inverse direction, these gentlemen conjectured, that it ought to be accelerated by every force, that would attract the fluids from within to without; and such a force they conceive inspiration to be, which, in their view, solicits the fluids of the economy to the lungs, in the same mechanical manner as it occasions the entrance of air into the air-cells. In support of this view they adduce the following experiments. To the trachea of a dog a pipe, communicating with a bellows, was adapted, and the thorax was largely opened. Natural respiration was immediately suspended; but artificial respiration was kept up by means of the bellows. The surface of the air-cells was, in this way, constantly subjected to the same pressure, there being no longer diminished pressure during inspiration, as when the thorax is sound, and the animal breathing naturally. Six grains of camphorated spirit were now injected into the peritoneum; and, at the same time, a similar quantity in another dog, whose respiration was

[1] Précis, &c., ii. 348.

[2] Tiedemann and Treviranus, Zeitschrift für Physiologie, Band. v. H. ii.; cited in British and Foreign Medical Review, i. 241, Lond., 1836.

[3] Recherches Expérimentales sur l'Exhalation Pulmonaire, Paris, 1826.

natural. In the course of from three to six minutes, the odorous substance was detected in the pulmonary transpiration of the latter; but in the other it was never manifested. They now exposed in the first animal a part of the muscles of the abdomen, and applied a cupping-glass to it; when the smell of the camphor speedily appeared at the cupped surface. Their conclusion was, that the pulmonary surface, having ceased to be subjected to the suction force of the chest during inspiration, exhalation was arrested, whilst that of the skin was developed as soon as an action of aspiration was exerted upon it by the cupping-glass.

Into the crural veins of two dogs,—one of which breathed naturally, and the other was circumstanced as in the last experiment,—they injected essential oil of turpentine. In the first of these, the substance was soon apparent in the pulmonary transpiration; and, on opening the body, it was discovered, that the turpentine had impregnated the lung and pleura much more strongly than the other tissues. In the other animal, on the contrary, the odour of the turpentine was scarcely apparent in the vapour of the lungs; and on dissection, it was not found in greater quantity in the lungs than in other tissues;—in the pleura, for instance, than in the peritoneum.

From the results of these experiments, MM. Breschet and Edwards conclude, that each inspiratory movement constitutes a kind of suction, which attracts the blood to the lungs; and causes the ejection of the liquid and gaseous substances which are mingled with that fluid, through the pulmonary surface, more than through the other exhalant surfaces of the body. In their experiments, these gentlemen did not find, that exhalation was effected with equal readiness in every part of the surface, when the cupping-glass was applied in the mode that has been mentioned. The skin of the thigh, for example, did not indicate the odour of camphorated alcohol as did that of the region of the stomach.

The chemical composition of the pulmonary transpiration appears to be water, holding in solution, perhaps, some saline and albuminous matter; but our information on this subject, derived from the chemist, is not precise. M. Collard de Martigny's[1] experiments make it consist, in 1000 parts,—of water 907, carbonic acid 90; animal matter—the nature of which he was unable to determine—3. M. Chaussier found, that by keeping a portion of it in a close vessel exposed to an elevated temperature, a very evident putrid odour was exhaled on opening the vessel. This could only have arisen from the existence of nitrogenized matter in it.

The pulmonary transpiration being liable to all the modifications which affect the cutaneous, it is not surprising, that we should meet with so much discordance in the estimates of different individuals, regarding its quantity in a given time. Hales[2] valued it at 20 ounces in the twenty-four hours: Sanctorius,[3] Menzies,[4] and Dr. William Wood,[5]

[1] Magendie's Journal de Physiologie, x. 111.

[2] Statical Essays, ii. 322, Lond., 1767.

[3] Medicina Statica, Aphor. v.

[4] Dissertation on Respiration, p. 54, Edinb., 1796.

[5] Essay on the Structure, &c., of the Skin, Edinb., 1832.

at 6 ounces; Mr. Abernethy[1] at 9 ounces; MM. Lavoisier and Séguin[2] at 17½ ounces *poids de marc;* Dr. Thomson[3] at 19 ounces, Dr. Dalton at from 1 pound 8¾ ounces,[4] to 20½ ounces avoirdupois,[5] Dr. Carpenter[6] at from 16 to 20 ounces, and Kirkes and Paget[7] at from 6 to 27 ounces. The uses it serves in the animal economy are identical with those of the cutaneous transpiration. It is essentially depuratory. Experiments, some of which have been detailed, have sufficiently shown, that volatile substances introduced in any way into the circulatory system, if not adapted for the formation of arterial blood, are rapidly exhaled into the bronchial tubes. Independently, therefore, of the lungs being the great organs of respiration, they play a most important part in the economy, by throwing off those substances, that might be injurious, if retained.

2. *Menstrual Exhalation.*

The secretion of the menstrual fluid, which is mainly a sanguineous exhalation from the vessels of the uterus, will fall more appropriately under consideration when treating of the functions of reproduction.

3. *Gaseous Exhalation.*

The secretion of air from the bloodvessels is not so manifest as in the case of the exhalations thus far considered; but if we regard, with many, the separation of carbonic acid from the blood as a secretion, it is one of the most extensive and important in the animal economy. Gases are perpetually received into the vessels of the lungs, and to a certain degree elsewhere, whilst under the function of Respiration it has been seen, that carbonic acid is constantly exhaled. Moreover, in the swim-bladders of fishes an unequivocal case of gaseous secretion is presented; for many of these have no communication whatever, by duct or otherwise, with any outlet of the body. In the order *Pharyngognathi* of Müller, which includes the family of the saury pike and others; in *Anacanthini*, including the cod and plaice; in *Acanthopteri*, including the perch, gurnard, mullet, mackerel, and others; in the *Plectognathi* of Cuvier, including the globe fish; and in *Lophobranchii* of the same naturalist, which includes the sea horse and pipe fish,—a characteristic is the possession of a swim bladder without an air duct. In these cases, there can be no question of the secretion of air; and accordingly such a secretion has been admitted by physiologists.[8] It may account for the copious developement of air in the intestinal canal, as has been suggested elsewhere;[9] and for the production of many of the pneumatoses, which are so difficult of explanation under any other

[1] Surgical and Physiol. Essays, p. 141, Lond., 1793.

[2] Mém. de la Société Royale de Médecine, pour 1782–3; Annal. de Chimie, v. 264; and Mém. de l'Acad. des Sciences, pour 1789.

[3] System of Chemistry, vol. iv.

[4] Manchester Memoirs, 2d series, ii. 29.

[5] Ibid., vol. v.

[6] Human Physiology, § 549, Lond., 1842.

[7] Manual of Physiology, 2d Amer. edit., p. 139, Philad., 1853.

[8] John Hunter, Observations on Certain Parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 127, Philad., 1840. J. Vogel, The Pathological Anatomy of the Human Body, by Dr. Day, p. 31, London, 1847; and Prof. Owen, Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals, p. 272, Lond., 1846.

[9] Page 185.

view. The last subject has, however, received the author's attention in another work.[1]

II. FOLLICULAR SECRETIONS.

Follicular secretions are effected from the skin or the mucous membranes. They may be divided into two great classes;—1st, the *follicular secretions of mucous membranes;* and 2dly, the *follicular secretions of the skin.*

1. *Follicular Secretion of Mucous Membranes.*

The whole extent of the mucous membranes lining the alimentary canal, air-passages, and urinary and genital organs, is the seat of a secretion, the product of which has received, in the abstract, the name of *mucus;* although it differs somewhat according to the situation and character of the particular follicles whence it proceeds. Still, essentially, the structure, functions, and products of all mucous membranes are the same.[2] Such is the general sentiment. M. Donné,[3] however, ranges the different mucous membranes in three great divisions—according to their microscopical characters, the chemical reaction of their mucus, and the structure of the epithelium. His *first* division comprises those membranes that are analogous to the skin,—in other words, that secrete an acid fluid, which contains, under the form of pellicles, or scales, the product of the desquamation of the epidermis. They are, in reality, reflections of the outer skin, and in no respect deserve the name of mucous membranes. The vaginal mucous membrane is one of these, being a mere reflection of the outer skin, and possessing its principal properties. It secretes a mucus, which is always acid; strongly reddening litmus paper, and filled with soft, flattened lamellæ, or rather cells, like the epidermic vesicles of the skin. In regard to its physiological properties, this membrane, like the skin, is endowed with exquisite sensibility; it is scarcely ever the seat of hemorrhage, and ulcerates less readily than mucous membranes properly so called. The membranes with acid mucus and epidermic vesicles never, he says, exhibit any epidermic cells. The *second* division comprises the "true mucous membranes." They differ from the skin in every respect,—both by the nature of their epithelium, and the chemical reaction of their secretion, which is always alkaline. It is viscid, and, instead of exhibiting under the microscope the epidermic lamellæ or cellules, mentioned above, it presents only mucous globules, whose structure, properties, and origin are entirely different. These membranes, of which the bronchial mucous membrane may be taken as the type, ulcerate readily; are the seat of hemorrhages, and do not possess tactile sensibility like the skin. To these belong the vibratile organs or cilia.

These two orders of membranes, according to M. Donné, are found approximated, and almost confounded, although still preserving their distinct characters, in the vagina and neck of the uterus,—the one secreting a creamy, not ropy, always acid mucus; and presenting,

[1] Practice of Medicine, 3d edit., i. 172, Philad., 1848.
[2] See Mucous Membranes, under the Sense of Touch.
[3] Cours de Microscopie, p. 143, Paris, 1844.

under the microscope, large epidermic cellules; the other furnishing a glairy, ropy mucus, constantly alkaline, and containing mucous globules much smaller than epidermic cells, and of a structure and composition wholly different. The *third* division comprises a class intermediate between the two others, constituted by parts which participate in the organization of skin and mucous membranes, through surfaces which have not yet entirely lost the qualities of the external membrane, and already possess some of those of the internal or true mucous membranes. Such are the orifices where the skin does not terminate suddenly, but becomes gradually transformed into mucous membrane, as at the mouth, nose, anus, &c. These parts secrete a mucus, which M. Donné terms *mixed:* in this are found combined the characters of the two already mentioned, with a predominance of the one or the other, according as the properties of the skin, or those of the mucous membranes, prevail. The mucus of the mouth he regards as an example of the intermediate species.[1]

In the history of the different functions, in which certain of the mucous membranes are concerned, the uses of the secretion have been detailed; and in those functions, that will hereafter have to engage attention, in which other mucous membranes are concerned, its uses will fall more conveniently under notice. But few points will, therefore, require explanation at present.

The mucus secreted by the nasal follicles seems alone to have been subjected to chemical analysis. MM. Fourcroy and Vauquelin[2] found it composed of the same ingredients as tears. According to the analysis of Berzelius,[3] its contents are as follows:—water, 933·7; mucin 53·3; chlorides of potassium and sodium, 5·6; lactate of soda with animal matter, 3·0; soda, 0·9; albumen and animal matter, soluble in water, but insoluble in alcohol, with a trace of phosphate of soda, 3·5. Dr. G. O. Rees[4] considers mucus to be a compound of albumen in a state of close combination with alkaline salts, and probably free alkali; and he affirms, that the artificial compound formed by the addition of alkalies and neutral salts to albuminous matter is essentially the same as mucus.

According to M. Raspail,[5] mucus is the product of the healthy and daily disorganization or wear and tear of mucous membranes. Every mucous membrane, he affirms, exfoliates in organized layers, and is thrown off, more or less, in this form; but the serous membranes either do not exfoliate, or their exfoliation (*excoriation*) is reduced to a liquid state to be again absorbed by the organs. When examined by a microscope of high magnifying power, mucus presents here and there, appearances of shreds similar to those described by M. Raspail. These have been considered by recent histologists detached epithelium cells, with granulated globular particles, which are esteemed to be

[1] See, on the structure, relations, and offices of the Mucous Membranes, Mr. Bowman, art. Mucous Membrane, in Cyclop. of Anat. and Physiol., Parts xxiii. and xxiv., Lond., 1842.

[2] Journal de Physique, xxxix. 359.

[3] Medico-Chirurg. Transactions, tom. iii.; also, Thomson, Chemistry of Animal Bodies, p. 507, Edinb., 1843.

[4] Cyclop. of Anat. and Physiol., P. xxiii. p. 484, April, 1842.

[5] Chimie Organique, p. 246, and p. 504, Paris, 1832.

characteristic of the secretion from the surface of mucous membranes.[1] It is never free from epithelium of the mucous membrane whence it originated; and, according to Lehmann,[2] may be said to consist almost entirely of epithelium, which seems to be held together only by means of a pellucid juice.

Although mucus is classed as a follicular secretion, it would seem to be formed in mucous membranes in which no follicles can be detected, as in those lining the frontal and other sinuses of the cranium. M. Mandl,[3]—who first stated the belief in the identity in structure of the globules of mucus and pus and the red corpuscles of the blood,—describes mucus as composed of a viscid liquid in which are swimming, besides lamellæ of epithelium, special elements, which he calls *globules of mucus.* These are of two kinds,—the one consisting of mammillated corpuscles, 0·005 to 0·006 of a *millimètre* in diameter; the other, from 0·01 to 0·02 of a *millimètre* in diameter,—the latter being true cells, composed of an envelope and a nucleus.

The great use of mucus, wherever met with, is to lubricate the surface on which it is poured. Experiments, however, by Oesterlen[4] have proved the influence of the layer of mucus, which lines the digestive canal, in retarding both the imbibition of fluids inclosed within the canal, and the permeation of fluids by endosmose. The passage of fluid into, or through, the mucous membrane of the intestines was, in many cases, more than twice as rapid when the mucus had been removed as when still adherent.

2. *Follicular Secretion of the Skin.*

This is the sebaceous and micaceous humour, observed in the skin of the cranium, and in that of the pavilion of the ear. It is, also, the humour, which occasionally presents the appearance of small worms beneath the skin of the face, when it is forced through the external aperture of the follicle; and when exposed to the air causes the black spots sometimes observable on the face.

The following were found by Esenbeck[5] to be its constituents: fat, 24·2; osmazome, with traces of oil, 12·6; watery extractive matters, 11·6; albumen and casein, 24·2; carbonate of lime, 2·1; phosphate of lime 20·0; carbonate of magnesia, 1·6; acetate of soda, and chloride of sodium, traces.

The cutaneous or miliary follicles or glands are referred to elsewhere, in describing the anatomy of the common integument. At times, they are simple crypts, formed merely by an inversion of the common integument; at others, more complicated but still a like inversion; and they usually open into channels by which the hairs issue. (Fig. 147, 2.)

In certain parts of the skin, they are more numerous than in others. Mr. Rainey was unable to detect them in the palms of the hands and

[1] For the different forms of mucus. see Donné. op. cit., p. 145.

[2] Lehrbuch der Physiologischen Chemie, ii. 361. Leipz., 1850; or Amer. edit. of Dr. Day's translation by Dr. R. E. Rogers, ii. 85, Philad., 1855.

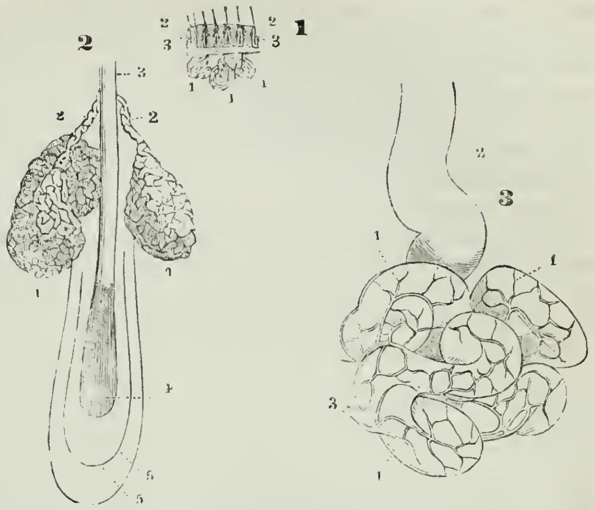
[3] Manuel d'Anatomie Générale. p. 478, Paris, 1843.

[4] Beiträge zur Physiologie des Gesunden und Kranken Organismus, S. 245, Jena, 1843.

[5] V. Bruns, Lehrbuch der Allgemeinen Anatomie, S. 353, Braunschweig, 1841.

soles of the feet. Their appearance in the axilla of the negro has been described by Professor Horner.[1] Their granular or composite character in the axilla, he thinks, is sufficiently evident; but the point is yet to be settled, whether their excretory ducts have the tortuous arrangement of those of the ceruminous glands, or whether they be branched and racemose, like those of the salivary. Mr. Hassall[2] affirms, that they are similar in organization to the sudoriparous glands, but much larger.

Fig. 147.



Sebaceous or Oil Glands and Ceruminous Glands.

1. *Section of skin, magnified three diameters.* 2, 2. Hairs. 3, 3. Superficial sebaceous glands. 1, 1. Larger and deeper-seated glands by which the cerumen appears to be secreted. **3**. *A ceruminous gland more largely magnified,* formed of convoluted tube 1, forming excretory duct 2. 3. A small vessel, and its branches. **2**. *A hair from meatus auditorius,* perforating epidermis at 3, and at 4, contained within its double follicle, 5, 5. 1, 1. Sebaceous follicles of hair with their excretory ducts.

Fig. 148.

Cutaneous Follicles or Glands of the Axilla, magnified one-third.

The secretion from the different cutaneous follicles differs, probably, according to the different character and arrangement of animal membrane from which the cells that form it are developed. There is, certainly, a marked difference between the fluids secreted in the axilla, groin, prepuce, feet, &c., each appearing to have its characteristic odour;

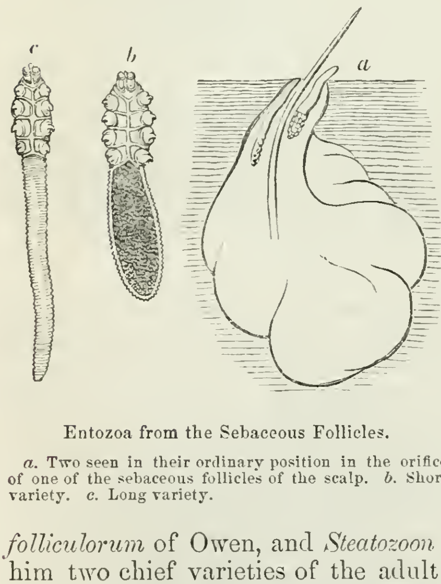
[1] American Journal of the Medical Sciences, for January, 1846, p. 13.
[2] The Microscopic Anatomy of the Human Body, Part xiii. p. 426, Lond., 1848.

although a part of this may be owing to changes occurring in the matter of secretion by retention in parts to which the free access of air is prevented. The cutaneous or miliary glands, depicted by Dr. Horner, are considered by him to be the *glandulæ odoriferæ* of the axilla. In many animals odorous secretions of a similar character are formed by special organs; but whether the scent peculiar to animals and to races is thus secreted is canvassed elsewhere, and must be regarded as somewhat unsettled.

The *cerumen* is a follicular secretion, as well as the whitish, odorous and fatty matter—*smegma*—which forms under the prepuce of the male, and in the external parts of the female, where cleanliness is disregarded. The *humour of Meibomius* is also follicular, as well as that of the caruncula lacrymalis, of the crypts around the base of the nipple, &c.

The use of these secretions is to favour the functions of the parts over which they are distributed. That which is secreted from the skin is spread over the epidermis, hair, &c., giving suppleness and elasticity to the parts; rendering the surface smooth and polished, and thus obviating the evils of abrasion that might otherwise arise. It is also conceived, that its unctuous nature may render the parts less permeable to humidity.

Fig. 149.



Entozoa from the Sebaceous Follicles.

a. Two seen in their ordinary position in the orifice of one of the sebaceous follicles of the scalp. *b.* Short variety. *c.* Long variety.

In the ducts of the sebaceous follicles, a parasite was discovered by M. Simon, of Berlin;[1] which has been minutely described by Mr. Erasmus Wilson,[2] Professor Vogel,[3] Messrs. Todd and Bowman,[4] and Professor Owen.[5] It is the *Acarus folliculorum* of Simon, *Demodex folliculorum* of Owen, and *Steatozoon folliculorum* of Mr. Wilson. By him two chief varieties of the adult animal are depicted. These are mainly distinguished by their length—the one measuring from the $\frac{1}{100}$th to the $\frac{1}{45}$th, the other from the $\frac{1}{100}$th to the $\frac{1}{109}$th of an inch. The marginal figure represents them as found by Messrs. Todd and Bowman in a sebaceous follicle of the scalp. They do not appear to be of any physiological or pathological importance.

[1] Müller's Archiv., s. 218, 1842.

[2] On Diseases of the Skin, 2d Amer. edit., p. 424, Philad., 1847; and in Philosophical Transactions for 1844.

[3] The Pathological Anatomy of the Human Body; translated by Dr. Day, p. 453, Lond., 1847.

[4] The Physiological Anatomy and Physiology of Man, p. 425, Lond., 1845.

[5] Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals, p. 251, Lond., 1843.

3. *Secretion of the Ovaries.*

The secretion of the ovaria—the formation of ova—is accomplished in the follicles of De Graaf. They are devoid of outlet; and the secretion has to make its way to the surface of the ovary and be discharged,—the Fallopian tube receiving it, and acting as an excretory duct. The mode in which this is accomplished falls more appropriately under consideration, when the functions of Reproduction are investigated.

III. GLANDULAR SECRETIONS.

The glandular secretions are seven in number; the transpiration, tears, saliva, pancreatic juice, bile, urine, sperm, and milk.

1. *Transpiratory Secretion of the Skin.*

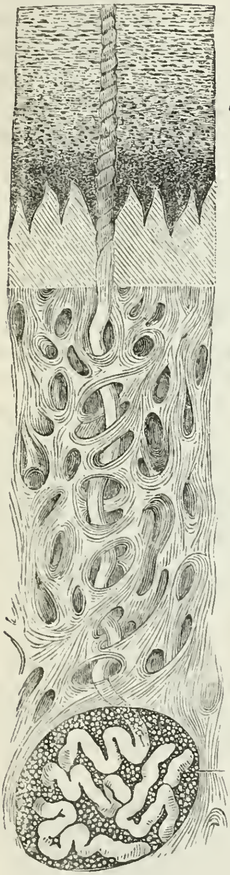
A transparent fluid is constantly exhaled from the skin, which is generally invisible in consequence of its being converted into vapour as soon as it reaches the surface; but, at other times, owing to augmentation of the secretion, or to the air being loaded with humidity, it is apparent on the surface of the body. When invisible, it is called *insensible transpiration* or *perspiration;* when perceptible, *sweat.* In the state of health, according to M. Thénard,[1] this fluid reddens litmus paper; yet the taste is rather saline—resembling that of common salt—than acid. Wagner,[2] indeed, affirms that it generally shows alkaline reaction; and, at other times, does not affect vegetable blues; but the sweat of many parts of the body,—the armpits for example,—is said always to react like an alkali. Allusion has already been made to the views of M. Donné,[3] who considers, that the external, and the internal alkaline membranes of the human body represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer.

The smell of the perspiration is peculiar, and when concentrated, and especially when subjected to distillation, becomes almost insupportable. The fluid is composed, according to M. Thénard, of much water, a small quantity of acetic acid, chloride of sodium, and perhaps of potassium, a very little earthy phosphate, a trace of oxide of iron, and an inappreciable quantity of animal matter. Berzelius[4] regards it as water holding in solution chlorides of potassium and sodium, lactic acid, lactate of soda, and a little animal matter; Anselmino,[5] as consisting of a solution of osmazome, chlorides of sodium and calcium, acetic acid, and an alkaline acetate, salivary matter, sulphates of soda and potassa, and calcareous salts, with mucus, albumen, sebaceous humour, and gelatin in variable proportions; and M. Raspail[6] looks upon it as an acid product of the disorganization of the skin. The solid constituents, according to Simon,[7] are a mixture of salts and ex-

[1] Traité de Chimie, tom. iii.
[2] Elements of Physiology, by R. Willis, § 204, Lond., 1842.
[3] Journal Hebdomad., Février, 1834.
[4] Medico-Chir. Trans., iii. 256.
[5] Lepelletier, Physiologie Médicale et Philosophique, ii. 452, Paris, 1832.
[6] Chimie Organique, p. 505, Paris, 1832.
[7] Animal Chemistry, Sydenham Society's edit., ii. 101, Lond., 1846.

tractive matters, of which the latter preponderate: the principal ingredient of the salts is chloride of sodium. From what he admits to be superficial and merely qualitative investigations, he considers he has established the existence in normal sweat, of —*First.* Substances soluble in ether; traces of fat, sometimes including butyric acid. *Secondly.* Substances soluble in alcohol; alcohol extract; free lactic or acetic acid; chloride of sodium; lactates and acetates of potassa and soda; lactate or chlorohydrate of ammonia. *Thirdly.* Substances soluble in water; water extract; phosphate of lime, and occasionally an alkaline sulphate; and, *fourthly.* Substances insoluble in water; desquamated epithelium; and—after the removal of the free lactic acid by alcohol—phosphate of lime with a little peroxide of iron. In the solid matter urea was detected by Landerer,[1] and also by M. Favre,[2]—whose researches are more complete and exact than any perhaps that had been before undertaken. He found the constituents of human sweat to be as follows: chloride of sodium, 2·2305; chloride of potassium, 0·2437; alkaline sulphates, 0·0115; phosphoric acid, traces; earthy phosphate, traces; calcareous salts, traces; alkaline albuminate, 0·0050; epithelium, lactates of potassa, traces; and soda, 0·3171; hydrotates,[3] 1·5623; urea, 0·0428; fat, 0·0136; water, 995·5733. Schottin,[4] however, was unable to detect either urea or ammonia in the matter of perspiration.

Fig. 150.



Vertical Section of the Skin of the Sole.

a. Cuticle; the deep layers (rete mucosum) more coloured than the upper, and their particles rounded; the superficial layers more and more scaly. *b.* Papillary structure. *c.* Cutis. *d.* Sweat-gland, lying in a cavity on the deep surface of the skin, and imbedded in globules of fat. Its duct is seen passing to the surface. Magnified 40 diameters.

After evaporation upon a clean glass plate, fragments of epidermic cells are generally observed in it, and crystals are left behind, which are those of its contained salts. With great care to avoid admixture, Krause[5] collected a small quantity of pure cutaneous perspiration from the palm of the hand, where there are no sebaceous follicles. The fluid yielded, with boiling ether, some small globules of oil and crystals of margarin. It was acid, but after twenty-four hours became alkaline by the developement of ammonia.

[1] G. O. Rees, art. Sweat, Cyclopædia of Anatomy and Physiology, pt. xxxvii. p. 844, Lond., October, 1849.

[2] Comptes Rendus, xxxv. 721; Archives Générales de Méd., Juillet, 1853; and Becquerel and Rodier, Traité de Chimie Pathologique, p. 525, Paris, 1854.

[3] M. Favre affirms that he discovered a new nitrogenous acid in the sweat, which he calls the *hydrotic* or *sudoric.*

[4] Canstatt, Ibid., S. 120.

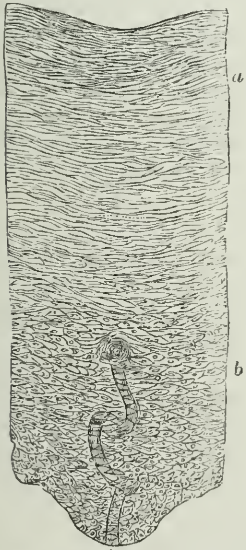
[5] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7te Lieferung, S. 108.

In another experiment, he found, that the tissue of the epidermis contains a fatty substance independently of the fatty matter secreted on its surface.

In a memoir presented to the *Académie Royale des Sciences* of Paris, MM. Breschet and Roussel de Vauzème first clearly showed, that there exists in the skin an apparatus for the secretion of the sweat, consisting of a glandular parenchyma, which secretes the liquid, and of ducts, which pour it on the surface of the body. These ducts are arranged spirally, and open very obliquely under the scale of the epidermis. To this apparatus they applied the epithet "*diapnogenous;*" and called the ducts "*sudoriferous* or *hidrophorous.*"[1]

Each *sudoriparous gland* consists of a coil or excretory duct surrounded by bloodvessels, and imbedded in fat vesicles. Thence the duct passes in the manner represented in the marginal figure, towards the surface, and opens on the epidermis by an oblique valve-like aperture. The excretory duct is lined by epithelium, which is a prolongation of the epidermis. These glands are numerously distributed; but especially so in the palms of the hand, and soles of the foot. In the

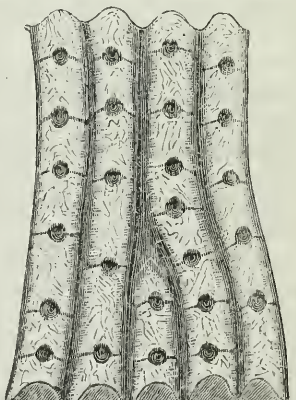
Fig. 151.



Vertical Section of Epidermis, from Palm of the Hand.

a. Outer portion, composed of flattened scales. *b.* Inner portion, consisting of nucleated cells. *c.* Tortuous perspiratory tube, cut across by the section higher up.—Magnified 155 diameters.

Fig. 152.



Surface of the Skin of the Palm, showing the Ridges, Furrows, Cross-grooves, and Orifices of the Sweat-ducts.

The scaly texture of the cuticle is indicated by the irregular lines on the surface.—Magnified 20 diameters.

former situation they amount, according to Professor Krause,[2] to 2736 in every square inch; and in the latter, to 2685. Mr. E. Wilson[3]

[1] Op. cit., s. 131.
[2] Breschet, Nouvelles Recherches sur la Structure de la Peau, Paris, 1835.
[3] Healthy Skin, p. 42, Lond., 1845; or Amer. edit., p. 63, Philad., 1854.

counted the perspiratory pores on the palm of the hand, and found 3528 in a square inch; and each of these pores being the aperture of a little tube of about a quarter of an inch long, it follows, that in a square inch of skin, on the palm of the hand, there exists a length of tube equal to 882 inches, or $73\frac{1}{2}$ feet. To obtain an estimate of the length of tube of the perspiratory system of the whole surface of the body, he thinks that 2800 might be taken as a fair average of the number of pores in the square inch; and 700, consequently, of the number of inches in length. "Now the number of square inches of surface in a man of ordinary height and bulk is 2500; the number of pores, therefore, 7,000,000, and the number of inches of perspiratory tube, 1,750,000; that is, 145,833 feet or 48,600 yards, or nearly 28 miles!"

Numerous experiments have been instituted for the purpose of discovering the quantity of transpiration in a given time. Of these, the earliest were by Sanctorius,—for which he is more celebrated than for any of his other labours,—after whom the cutaneous transpiration was called *Perspirabile Sanctorianum.*[1] For thirty years, this indefatigable experimentalist weighed daily, with the greatest care, his solid and liquid ingesta and egesta, and his body, with the view of deducing the loss sustained by the cutaneous and pulmonary exhalations. He found, that every twenty-four hours his body returned to the same weight, and that he lost the whole of the ingesta;—five-eighths by transpiration, and three-eighths by the ordinary excretions. For eight pounds of ingesta there were only three pounds of sensible egesta, which consisted of forty-four ounces of urine, and four of fæces. It is lamentable to reflect, that so much time was occupied in the attainment of such insignificant results. The self-devotion of Sanctorius gave occasion, however, to the institution of numerous experiments of the same kind; as well as to discover the variations in the exhalation, according to age, climate, &c. The results of these have been collected by Haller,[2] but they afford little instruction; especially as they were directed to the transpiration in general, without affording any data from which to calculate the proportion exhaled from the lungs compared with that constantly given off by the cutaneous surface. Rye,[3] who dwelt in Cork, lat. 51° 54′, found, in the three winter months—December, January, and February—that the quantity of urine was 3937 ounces; of perspiration, 4797; in the spring months—March, April, and May—the urine amounted to 3558; the perspiration to 5405; in the summer months—June, July, and August—the former amounted to 3352; the latter to 5719; and in the three autumnal months—September, October, and November—the quantity of urine was 3369; of perspiration, 4471. The daily average estimate in ounces was as follows:—

	Urine.	Perspiration.
Winter, ...	$42\frac{7}{10}$	53
Spring, ...	40	60
Summer, ...	37	63
Autumn, ...	37	50

Thus making the average daily excretion of urine, throughout the

[1] Ars Sanctorii de Staticâ Medicinâ, cum Comment. Martini Lister, Lugd. Bat., 1711.
[2] Elem. Physiol., xii. 2, 10.
[3] Rogers on Epidem. Diseases, Appendix, Dubl., 1734.

year, to be a little more than 39 ounces; and of the transpiration, 56 ounces. Keill,[1] on the other hand, makes the average daily perspiration, 31 ounces; that of the urine, 38; the weight of the fæces being 5 ounces, and of the solid and liquid ingesta, 75. His experiments were made at Northampton, England, lat. 52° 11′. Bryan Robinson[2] found, as the result of his observations in Ireland, that the ratio of the perspiration to urine was, in summer, 5 to 3; in winter, 2 to 3; whilst in April, May, October, November, and December, they were nearly equal. In youth, the ratio of the perspiration to urine was 1340 to 1000; in the aged, 967 to 1000. Hartmann, when the solid and liquid ingesta amounted to 80 ounces, found the urine discharged 28 ounces; the fæces, 6 or 7 ounces; and the perspirable matter, 45 or 46 ounces. De Gorter,[3] in Holland, when the ingesta were 91 ounces, found the perspiration amount to 49 ounces; the urine to 36; and the fæces to 8. Dodart[4] asserts, that, in France, the ratio of the perspiration to the fæces is as 7 to 1; and the whole egesta 15 to 12 or 10. The average perspiration in the twenty-four hours, he estimates at 33 ounces and two drachms; and Sauvages, in the south of France, found, that when the ingesta were 60 ounces in the day, the transpiration amounted to 33 ounces; the urine to 22; and the fæces to 5. But most of these estimates were obtained in the cooler climates,—the "*regiones boreales*,"—as Haller[5] has, not very happily, termed them.

According to Lining,[6] whose experiments were made in South Carolina, lat. 32° 47′, the perspiration exceeded the urine in the warm months; but in the cold, the latter had the preponderance. The following table, quoted by Haller, gives the average daily proportion of urine and perspiration, for each month of the year, in ounces.

	Urine.	Perspiration.
December,	70·81	42·55
January,	72·43	39·97
February,	77·86	37·45
March,	70·59	43·23
April,	59·17	47·72
May,	56·15	58·11
June,	52·90	71·39
July,	43·77	86·41
August,	55·41	70·91
September,	40·60	77·09
October,	47·67	40·78
November,	63·16	40·97

After the period at which Haller wrote, no experiments of any moment were made for appreciating the transpiration. Whenever trials were instituted, the exhalation from both the skin and lungs was included in the result, and no satisfactory means were adopted for separating them, until MM. Lavoisier and Séguin[7] made their celebrated experiments. M. Séguin enclosed himself in a bag of gummed taffeta, which was tied above the head, and had an aperture the edges

[1] Tentamina Medico-Phys., Appendix, Lond., 1718.
[2] Dissertation on the Food and Discharges of Human Bodies, Dublin, 1748.
[3] De Perspiratione Insensibili, Lugd. Bat., 1736.
[4] Mémoir. de l'Acad. des Sciences, ii. 276.
[5] Op. cit.
[6] Philos. Transact. for 1743 and 1745.
[7] Mémoir. de l'Acad. des Sciences de Paris, Paris, 1777 and 1790.

of which were fixed around the mouth by a mixture of turpentine and pitch. By means of this arrangement, the pulmonary transpiration alone escaped into the air. To estimate its quantity, it was merely necessary for M. Séguin to weigh himself in the sac by a very delicate balance, at the commencement and termination of the experiment. By repeating it out of the sac, he determined the total quantity of transpired fluid; so that, by deducting from this the quantity of fluid exhaled from the lungs, he obtained the amount of cutaneous transpiration. He, moreover, kept an account of the food which he took; of the solid and liquid egesta; and, as far as he was able, of every circumstance that could influence the transpiration.

The results—as applicable to Paris, at which MM. Lavoisier and Séguin arrived, by a series of well-devised and well-conducted experiments—were the following:—*First.* Whatever may be the quantity of food taken, or the variations in the state of the atmosphere, the same individual, after having increased in weight by the whole quantity of nourishment taken, returns daily, after the lapse of twenty-four hours, to nearly the same weight as the day before;—provided he is in good health; his digestion perfect; not fattening nor growing; and avoids all kinds of excess. *Secondly.* If, when all other circumstances are identical, the amount of food varies; or if—the amount of food being the same—the effects of transpiration differ, the quantity of the excrements augments or diminishes, so that every day at the same hour we return nearly to the same weight; proving, that when digestion goes on well, the causes, that concur in the loss or excretion of the food taken in, afford each other mutual assistance,—in the state of health one charging itself with what the other is unable to accomplish. *Thirdly.* Defective digestion is one of the most direct causes of diminution of transpiration. *Fourthly.* When digestion goes on well, and the other causes are equal, the quantity of food has but little effect on the transpiration. M. Séguin affirms, that he has very frequently taken at dinner two pounds and a half of solid and liquid food; and at other times four pounds; yet the results in the two cases differed but little,—provided only the quantity of fluid did not vary materially in the two cases. *Fifthly.* Immediately after dinner, the transpiration is at its minimum. *Sixthly.* When all other circumstances are equal, the loss of weight induced by insensible transpiration is at its maximum during digestion. The increase of transpiration during digestion compared with the loss sustained when fasting, is, on an average, $2\frac{3}{10}$ grains per minute. *Seventhly.* When circumstances are most favourable, the greatest loss of weight caused by insensible transpiration was, according to their observations, 32 grains per minute; consequently, 3 ounces, 2 drachms and 48 grains *poids de marc*, per hour; and 5 pounds in twenty-four hours, under the calculation, that the loss is alike at all hours of the day, which is not, however, the fact. *Eighthly.* When all the accessory circumstances are least favourable, provided only that digestion is properly accomplished, the smallest loss of weight is 11 grains per minute; consequently, 1 ounce, 1 drachm and 12 grains per hour; and 1 pound, 11 ounces and 4 drachms in the twenty-four hours. *Ninthly.* Immediately after eating, the loss of weight caused by the insensible perspiration is $10\frac{1}{5}$ grains per minute during the time at which all the extraneous causes are most unfavourable to transpiration; and $19\frac{1}{10}$ grains per minute when these causes are most favourable, and the internal causes are alike. "These differences," says M. Séguin, "in the transpiration after a meal, according as the causes influencing it are more or less favourable, are not in the same ratio with the differences observed at any other time when the other circumstances are equal; but we know not how to account for the phenomenon." *Tenthly.* The cutaneous transpiration is immediately dependent both on the solvent virtue of the circumambient air, and the power possessed by the exhalants of conveying the perspirable fluid as far as the surface of the skin. *Eleventhly.* From the average of all the experiments it seems, that the loss of weight caused by the insensible transpiration is 18 grains per minute; and that, of these 18 grains, 11, on the average, belong to the cutaneous transpiration, 7 to the pulmonary. *Twelfthly.* The pulmonary transpiration, compared with the volume of the lungs, is much more considerable than the cutaneous, compared with that of the surface of the skin. *Thirteenthly.* When all other circumstances are equal, the pulmonary transpiration is nearly the same before and immediately after a meal; and if, on an average, it is $17\frac{1}{5}$ grains per minute before dinner, it is $17\frac{7}{10}$ grains after dinner. *Lastly.* All intrinsic circumstances being equal, the weight of the solid excrements is least during winter.

Although these results are probably fairly deduced from the experiments; and the experiments themselves almost as well conceived as the subject admits of, we cannot regard the estimates as more than approximations. Independently of the fact, that the envelope of taffeta must necessarily have retarded the exhalation, by shutting off the air, and causing more to pass off by pulmonary transpiration, the perspiration must incessantly vary, according to circumstances within and without the system: some individuals, too, perspire more readily than others; and the amount exhaled is dependent, as we have seen, upon climate and season,—and likewise upon the quantity of fluid received into the digestive organs.

From these and other causes, Bichat was led to observe, that the endeavour to determine the quantity of the cutaneous transpiration is as vain as to endeavour to specify what quantity of water is evaporated every hour on a fire, the intensity of which is varying every instant. To attempt, however, the solution of the problem, experiments were undertaken by Cruikshank,[1] and by Abernethy. Their plan consisted in confining the hand, for an hour, in an air-tight glass jar, and collecting the transpired moisture. Mr. Abernethy, having weighed the fluid collected in the glass, multiplied its quantity by $38\frac{1}{2}$, the number of times he conceived the surface of the hand and wrist to be contained in the whole cutaneous surface. This gave $2\frac{1}{2}$ pounds, as the amount exhaled from the skin in the twenty-four hours, on the supposition, that the whole surface perspires to an equal extent. These experiments have been repeated by Dr. William Wood,[2] of Newport, England, with some modifications. He pasted around the

[1] Experiments on the Insensible Perspiration, p. 5, Lond., 1795.

[2] An Essay on the Structure and Functions of the Skin, &c., Edinb., 1832.

mouth of a jar one extremity of a bladder the ends of which were cut away, and the hand being passed through the bladder into the jar, the other extremity was bound to the wrist with a ligature, not so tight, however, as to interfere, in any degree, with the circulation. The exact weight of the jar and bladder had previously been ascertained. During the experiment, cold water was applied to the outer surface of the jar, to cause the deposition of the fluid accumulated within. The result of his experiments was as follows:—

Exp.	Time of day.	Temperature in apartment.	Pulse per minute.	Fluid collected in an hour.
1	Noon.	66°	84	32 grs.
2	Do.	66	78	32
3	Do.	66	78	26
4	Do.	61	84	32
5	9 P.M.	62	80	26
6	Do.	62	75	23
	Mean	63·8	79·8	28·5

The next thing was to estimate the proportion, which the surface of the hand and wrist bears to the whole surface of the body. Mr. Abernethy reckoned it as 1 to 38½, and Mr. Cruikshank as 1 to 60! Dr. Wood does not adopt the estimate of either. He thinks, however, that the estimate of the former as regards the surface of the hand and wrist, which he makes seventy square inches, is near the truth, having found it correspond both with his own measurements and the reports of glovers. Mr. Abernethy's estimate of the superficial area of the whole body—2700 square inches, or above eighteen square feet, he regards as too high. Perhaps the most general opinion is, that it amounts to sixteen square feet, or 2304 square inches; but Haller did not think it exceeded thirteen square feet, or 2160 square inches. Dr. Wood adopts the former of these estimates, and is disposed to think, that the proportion of the surface of the hand and fingers, taken to the extremity of the bones of the arm, does not fall short of 1 to 2, which if we adopt the ratio of the quantity, he found transpired per hour, gives, for the whole body, about forty-five ounces, or nearly four pounds troy in the twenty-four hours. This is considerably above the result of the experiments of either Séguin or Abernethy; yet, on reviewing the experiments, Dr. Wood is not disposed to think it far from the truth.

Dr. Dalton, of Manchester, undertook a series of experiments similar to those of Sanctorius, Keill, Hartmann and Dodart.[1] The first he made upon himself in the month of March, for fourteen days in succession. The aggregate of the articles of food consumed in this time was as follows,—bread, 163 ounces avoirdupois; oaten cake, 79 ounces; oatmeal, 12 ounces; butcher's meat, 54½ ounces; potatoes, 130 ounces; pastry, 55 ounces; cheese, 32 ounces:—Total of solid food, 525½ ounces; averaging 38 ounces daily:—of milk, 435⅓ ounces; beer, 230 ounces; tea, 76 ounces;—Total of liquid food, 741½, averaging 53 ounces of fluid daily. The daily consumption was, consequently, 91 ounces; or nearly six pounds. During the same period, the total quantity of

[1] Manchester Memoirs, vol. v.

urine passed was 680 ounces; of fæces, 68 ounces—the daily average being,—of urine, $48\frac{1}{2}$ ounces; of fæces, 5 ounces: making $53\frac{1}{2}$ ounces. If we subtract these egesta from the ingesta, there will remain $37\frac{1}{2}$ ounces, which must have been exhaled by the cutaneous and pulmonary transpirations, on the supposition that the weight of the body remained stationary. To test the influence of difference of seasons, Dr. Dalton resumed his investigations in the month of June of the same year. The results were as might have been anticipated,—a less consumption of solids and a greater of fluids; a diminution in the evacuations and an increase in the insensible perspiration. The average of solids consumed per day was 34 ounces; of fluids, 56 ounces;—total, 90 ounces; the daily average of the evacuations—urine, 42 ounces; fæces, $4\frac{1}{3}$,—leaving a balance of nearly 44 ounces for the daily loss by perspiration, or one-sixth more than during the cooler season. He next varied the process, with the view of obtaining the quantity of perspiration, and the circumstances attendant upon it more directly. He procured a weighing beam, that would turn with one ounce. Dividing the day into periods of four hours in the forenoon, four or five in the afternoon, and nine in the night—or from ten o'clock at night to seven in the morning—he endeavoured to find the perspiration corresponding to these periods respectively. He weighed himself directly after breakfast, and again before dinner, observing neither to take, nor part with, any thing in the interval, except what was lost by perspiration. The difference in weight indicated such loss. The same course was followed in the afternoon and night. This train of experiments was continued for three weeks in November. The mean hourly losses by transpiration were;—in the morning, 1·8 ounce avoirdupois;—afternoon, 1·67 ounce; night, 1·5. During twelve days of this period he kept an account of urine corresponding in time with perspiration. The ratio was as 46 to 33. From the whole of his investigations on this subject, Dr. Dalton concludes;—that of six pounds of aliment taken in the day, there appears to be nearly one pound of carbon and nitrogen together; the remaining five pounds are chiefly water, which seems necessary as a vehicle to introduce the other two elements into the circulation, and also to supply the lungs and membranes with moisture;—that very nearly the whole quantity of food enters the circulation, for the fæces constitute only $\frac{1}{18}$th part, and of these a part—bile—must have been secreted;—that one great portion is thrown off by the kidneys, namely, about half of the whole weight taken, but probably more or less according to climate, season, &c.;—that another great portion is thrown off by means of insensible perspiration, which may be subdivided into two parts, one of which passes off by the skin—amounting to one-sixth part, and the other five-sixths are discharged from the lungs in the form of carbonic acid, and water or aqueous vapour.

M. Edwards[1] instituted experiments with the view of illustrating the effect produced upon cutaneous transpiration by various circumstances to which the body is subjected. His first trials were made on cold-blooded animals, in which the cutaneous transpiration can be

[1] Sur l'Influence des Agens Physiques, Paris, 1822; or translation by Hodgkin and Fisher, Lond., 1832.

readily separated from the pulmonary, owing to the length of time they are capable of living without respiring. All that was necessary was to weigh the animal before and after the experiment, and to make allowance for the ingesta and egesta. In this way he discovered, that the body loses successively less and less in equal portions of time;—that the transpiration proceeds more rapidly in dry than in moist air; in the extreme states nearly in the proportion of 10 to 1;—that temperature has, also, considerable influence,—the transpiration at 68° of Fahrenheit, being twice as much; and at 104°, seven times as much as at 32°. He likewise found, that frogs transpire, whilst they are in water, as is shown by the diminution they experience while immersed in that fluid, and by the appearance of the water itself, which becomes perceptibly impregnated with the matter excreted by the skin. In warm-blooded animals, as in the cold-blooded, the transpiration became less and less in proportion to the quantity of fluid evaporated from the body; and he observed the same difference between the effects of moist and dry air, as between a high and a low temperature. The effects of these agents were essentially the same on man as on animals. He found, that the transpiration was more copious during the early than the latter part of the day, and after taking food; and, on the whole, it appeared to be increased during sleep.

Whenever the fluid, which constitutes the insensible transpiration, does not evaporate, owing to causes referred to at the commencement of this article, it appears on the surface in the form of *sensible perspiration* or *sweat*. It has been supposed by some physiologists, that the insensible and sensible perspirations are two distinct functions. Such appears to be the opinion of Haller, and of M. Edwards, who regards the former as a physical *evaporation*,—the latter as a vital *transudation* or secretion; but no sufficient reason seems to exist, why we should not regard them as different degrees of the same function. It has been maintained, indeed, by Mr. Rainey,[1] as the results of careful histological inquiry, that there are no glands but the sudoriparous in the integument of the hands and feet, and hence it is inferred by him, that these glands furnish the oily or sebaceous matter with which these parts are anointed; and in place of regarding the sweat as an increase of the insensible perspiration, he esteems it an increased secretion of glands, which, in their less active state, secrete sebaceous matter, and, in their more active, the fluid of transpiration.

It has been affirmed, that the sweat is generally less charged with carbonic acid than the vapour of transpiration; and that it is richer in salts, which are deposited on the skin, and are sometimes seen in the form of white flocculi; but our knowledge on this matter is vague. There can be no doubt, however, that a large portion of the transpiration—pulmonary and cutaneous—consists of the fluid of evaporation,—the smaller portion, which is the true matter of perspiration, being the secretion of sudoriferous glands. To establish the amount of the fluids of evaporation and secretion, Krause[2] endeavoured both to num-

[1] Proceedings of the Royal Medical and Chirurgical Society, June 22, 1849, and London Med. Gaz., July 20, 1849.

[2] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7te Lieferung, S. 108, Braunschweig, 1844.

ber and measure these glands. On an average, he says, in each superficial square inch of the body there are 1000 orifices and glands of $\frac{1}{6}$th of a line in diameter; the greatest and least numbers in this space being, in the palm, 2736; in the sole, 2685; in the cheek, 548; in the neck, back, and nates, 417. The whole number, excluding the axilla, in which they are peculiarly large and thickset, is estimated at about 2,381,248. Adopting these numbers, and supposing each gland to be occupied by a column of fluid presenting at the orifice a hemispherical surface $\frac{1}{56}$th of a line in diameter—the size, which Krause found by admeasurement of some drops in a warm and moist, but not sweating skin—the whole of the glands would present an evaporating surface of 7896 square inches. Krause, therefore, considers it probable—according to ascertained laws of evaporation, and experiments instituted for the purpose—that only a portion of the fluid discharged by cutaneous transpiration is furnished by these glands; inasmuch as there could not be more than 3365 grains evaporated in the twenty-four hours from such a surface under favourable circumstances, whereas the experiments of MM. Lavoisier and Séguin—as has been shown—gave an average of 11 grains per minute, or 15,840 grains in the twenty-four hours,—leaving 12,475 grains to be accounted for probably by evaporation. But these are, of course, mere approximations to the truth.

Careful examinations have been made by Valentin[1] on his own person, in regard to the amount of both cutaneous and pulmonary transpiration. Taking three days of ordinary life in September, weighing himself naked fifteen times a day, and all his ingesta and sensible excretions, he found the averages of three days to be:—nutritive matter taken, 45325·5 grains; excrement, 2956·3 grains; urine, 22439·3 grains; perspiration, 19327·4 grains. The ingesta being as 1, the excrement was ·065, the urine, ·503; and the perspiration, ·422. There were differences, however, in the days;—in the first, the proportion of the ingesta to the excretions was as 1·097 to 1; in the second, as 1·028 to 1; in the third, as 1 to 1·090. The hourly amount of transpiration was occasionally $4\frac{1}{2}$ times as much as at others; the greatest difference being caused by whatever excited sweating, or perceptible moisture of the skin. For instance, on the same day, the hourly amount, after taking two cups of coffee, and during gentle perspiration, was 1213·65 grains; in the forenoon, in pretty active exercise and sweating, 1402·75 grains; and in the evening, during copious sweating from exercise, 2056·85 grains; but whilst writing quietly in the forenoon of the same day it fell to 858·7 grains, and three or four hours after dinner, it was only 509·95 grains. Nothing influenced the transpiration so much as rest and bodily exertion. Even when the latter did not produce manifest sweating, the effect was considerable. After eating, also, transpiration was generally increased, and its minimum was observed during fasting, and whilst at rest in a cool temperature. During the night and in sleep, the transpiration was diminished; but not more than in rest during the day. Mental exertion had no obvious influence.

[1] Lehrbuch der Physiologie des Menschen, B. i. S. 582; and Krause, op. cit., S. 140.

Particular parts of the body perspire more freely, and sweat more readily than others. The forehead, armpits, groins, hands, feet, &c., exhibit evidences of this most frequently; some of them perhaps, owing to the fluid, when exhaled, not evaporating readily,—the contact of air being impeded. It is presumed, likewise, that the sweat has not every where the same composition. Its odour certainly varies in different parts. In the armpits and feet it is generally considered to be more acid; but M. Donné[1] affirms, that there, as well as around the genital organs and between the toes, and wherever it is most odorous, it is alkaline, restoring the blue of litmus paper which had been previously reddened by an acid. He properly suggests, however, that this may be owing to admixture with the secretion of the follicles. In the violent sweats that accompany acute rheumatism, its acidity always attracts attention; and in the groins, its odour is strong and rank. It differs greatly, too, in individuals, and especially in races. In the red-haired, it is said to be unusually strong; and in the negro, during the heat of summer, alliaceous and overwhelming. By cleanliness, the red-haired can obviate the unpleasant effect in a great measure by preventing undue accumulation in the axillæ, groins, &c.; but no ablution can remove the odour of the negro, although cleanliness detracts from its intensity. Each race appears to have its characteristic odour; and, according to Humboldt, the Peruvian Indian, whose smell is highly developed by education, can distinguish the European, American Indian, and negro, in the middle of the night, by this sense alone. Certain anatomists and physiologists—as has been seen (p. 556)—have doubted, whether this special odorous matter of the skin belongs properly to the perspiration, and have presumed it to be the product of special organs. This is, however, by no means established; and the experiments of M. Thénard, as well as the facts just mentioned, would rather seem to show, that the matter of sweat itself has, within it, the peculiar odour. Simon,[2] too, affirms, that on evaporating his own sweat, the peculiar smell of the axilla was observed, and an odour of ammonia was developed: and allusion has been made to the recent view of Mr. Rainey, that the same glands may in one condition of activity furnish the matter of transpiration, and in another the ordinary secretion of sebaceous follicles. The fact of the dog tracing its master to an immense distance, and discovering him in a crowd, has induced a belief, that the scent may be distinct from the sweat; but the supposition is not necessary, if we admit the matter of perspiration to be itself odorous. There can be no doubt, however, that certain odorous secretions are formed by cutaneous follicles.

The singular fact has been stated, that by mixing fresh blood with one-third or one-half its bulk of strong sulphuric acid, and stirring the mixture with a glass rod, a peculiar odour is evolved, which differs in the blood of man and animals, and in the blood of the two sexes. This odour resembles that of the cutaneous perspiration of the animal. "They have hereby pretended to determine," says a modern medico-legal writer,[3] "whether any given specimen of blood had belonged to

[1] Cours de Microscopie, p. 207, Paris, 1844.
[2] Animal Chemistry, Sydenham Society's edition, ii. 102, Lond., 1846.
[3] Taylor, Medical Jurisprudence, Amer. edit., by Dr. Griffith, p. 275, Philad., 1845.

a man, a woman, a horse, sheep, or fish. Others pretend, that they have been able to identify the blood of frogs and fleas!" The first person who directed attention to this point was M. Barruel;[1] who was of opinion that a knowledge of the fact might be important in a medico-legal relation, with the view of determining the source of spots of blood on linen for example; but even admitting the fact, as stated by MM. Barruel, Devergie,[2] and others, it is obvious, that so much must depend upon the power of olfactory discrimination of the observer, that the evidence in any doubtful case could scarcely be deserving of much weight. Mr. Taylor, indeed, affirms, that there is probably not one individual among a thousand, whose sense of smell could be so acute as to allow him to state, with undeniable certainty, from what animal the unknown blood had really been taken.

Besides the causes before referred to, the quantity of perspiration is greatly augmented by running or violent exertion of any kind; especially if the temperature of the air be elevated. The amount will vary, however, according to the quantity of moisture already present in the air. If it be slight, a large quantity will pass off in the form of insensible perspiration; if the hygrometric condition be high, less will be exhaled in the insensible form, and more in the sensible. Experiments were made by Dr. Southwood Smith,[3] on eight of the workmen, employed at the Phœnix Gas Works in drawing and charging the retorts and making up the fires. They were weighed in their clothes immediately before they began, and after they had finished their labour; and in the interval between the first and second weighings they were not permitted to take any solids or liquids; nor to pass urine or fæces. Two men on a bright clear day worked in an unusually hot place for 70 minutes; the loss of weight of one of them was 4 lbs. 14 oz.; and of the other 5 lbs. 2 oz.

Warm fluids favour perspiration greatly; hence their use, alone or combined with sudorifics, when this class of medicines is indicated. M. Magendie[4] conceives, that being readily absorbed they are readily exhaled. This may be true; but the perspiration breaks out too rapidly to admit of this explanation. When ice-cold drinks are taken in hot weather, the cutaneous transpiration is instantaneously excited. The effect, consequently, must be produced by the refrigerant influence of the cold medium on the lining membrane of the stomach,—this influence being propagated, by sympathy, to every part of the capillary system. The same explanation is applicable to warm drinks; but the hot exert a sympathetic effect on the skin by virtue of their stimulant action on the mucous membrane.

With regard to the uses of the insensible transpiration, it has been supposed to preserve the surface supple, and thus favour the exercise of touch; and also, by undergoing evaporation, to aid in the refrigeration of the body. It is probable, however, that these are secondary uses under ordinary circumstances; and that the great office performed by it is to remove a certain quantity of fluid from the blood: hence it has been properly termed the *cutaneous depuration*. In this respect,

[1] Annales d'Hygiène, i. 267.
[2] Médecine Légale, 2de édit., iii. 761, Paris, 1840.
[3] Philosophy of Health, ii. 391–396.
[4] Précis de Physiologie, 2de édit., ii. 455.

it bears a striking analogy to the urine, which is the only other depuratory secretion, with the exception of the pulmonary transpiration, which we shall find essentially resembles the cutaneous. Being depuratory, it has been conceived, that any interruption to transpiration must be followed by serious consequences; accordingly most diseases have, from time to time, been ascribed to this cause. There is, however, so great a compensation existing between the urinary and cutaneous depurations, that if one be augmented, the other is decreased,—and conversely. Besides, it is well known, that disease is more apt to be induced by partial and irregular application of cold than by frigorific influences of a more general character. The Russian vapour-bath exemplifies this; the bather frequently passing with impunity from a temperature of 130° into cold water. The morbific effect—in these cases of fancied check given to perspiration—is derangement of the apparatus engaged in the important functions of nutrition, calorification, and secretion, and the extension of this derangement to every part of the organism.

As the *sensible transpiration* or *sweat* is probably only the insensible perspiration in increased quantity, with the addition of saline, and other matters that are not evaporable, its uses demand no special notice.

2. *Secretion of the Lachrymal Gland.*

The lachrymal apparatus, being a part of that accessory to vision, is described under another head.

The tears, as we meet with them, are not simply the secretion of the lachrymal gland, but of the conjunctiva, and occasionally of the caruncula lacrymalis and follicles of Meibomius. It has been presumed, too, by several modern ophthalmologists—by Wardrop, Rosas, Jüngken, for example—that a portion of them—Rognetta[1] says the principal portion—consists of the aqueous humour, which passes through the cornea by endosmose; but although such endosmose *may* exist, it can assuredly furnish but little towards the composition of the tears.[2] They have a saline taste; mix freely with water; and, owing to the presence of free soda, communicate a green tint to blue infusion of violets. Their chief salts are chloride of sodium, and phosphate of soda. According to MM. Fourcroy and Vauquelin,[3] the animal matter of the tears is mucus; but it is presumed, by some, to be albumen or an analogous principle—*dacryolin.* They found them to consist of water, mucus, chloride of sodium, soda, phosphate of lime and phosphate of soda. The following is the result of analyses by Professor Frerichs:[4]—

	I.	II.
Water,	99·06	98·70
Solid constituents,	0·94	1·30
Epithelium,	0·14	0·32
Albumen,	0·08	0·10
Chloride of Sodium—Alkaline Phosphates, Earthy Phosphates, Mucus, Fat,	0·72	0·88

[1] Traité Philosophique et Clinique d'Ophthalmologie, p. 705, Paris, 1844.

[2] Frerichs, Art. Thränensecretion, in Wagner's Handwörterbuch der Physiologie, 19te Lieferung, S. 621, Braunschweig, 1848.

[3] Journal de Physique, xxxix. 256.

[4] Op. cit., S. 618.

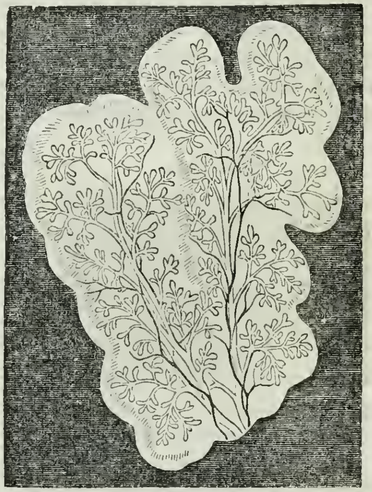
When tears are examined with the microscope, globules of mucus, and *debris* of the epidermis are seen in them.

This secretion is more influenced by the emotions than any other; and hence it is concerned in the expressions of lively joy or sorrow, especially the latter.

3. *Secretion of the Salivary Glands.*

The salivary apparatus has likewise engaged attention elsewhere. It consists of a *parotid* gland on each side, situate in front of the ear, and behind the neck and ramus of the jaw; a *submaxillary*, beneath the body of the bone; a *sublingual*, situate immediately beneath the tongue;—and an *intralingual* or *lingual*, seated at the inferior surface of the tongue;—the parotids and submaxillary glands having each but one excretory duct,—the sublingual several.[1] The racemose granular structure of the salivary glands in man greatly resembles that of the mammary glands. The marginal figure exhibits their structure in the sheep. All these glands pour their respective fluids into the mouth, where it collects, and becomes mixed with the exhalation of the mucous membrane of the mouth, and the secretion from its follicles. It is this mixed fluid that has generally been analyzed by the chemist. When collected without the action of sucking, it is of a specific gravity varying from 1·004 to 1·009; according to Mitscherlich, from 1·0061 to 1·0088. In the dog, Prof. Bernard[2] found that of the parotid to be from 1·0036 to 1·0041, whilst Jacubowitsch noted it in the same animal from 1·0040 to 1·0047. In the horse, Lehmann[3] found it to be from 1·0051 to 1·0074. It is translucent; slightly opaque; very frothy; and ultimately deposits a nebulous sediment. Even in the purest saliva there are always found mixed a few epithelial cells, derived from the mucous lining of the mouth, or from the excretory ducts of the secreting glands. It usually contains free alkali: in rare cases, during meals, Professor Schultz,[4] of Berlin, found it acid; and during fasting, it is occasionally neutral. Mitscherlich,[5] indeed, affirms, that it is acid whilst fasting; but becomes alkaline during eating,—the alkaline character disappearing, at times,

Fig. 153.



Lobules of the Parotid Gland, in the Embryo of the Sheep.

[1] Page 77.

[2] Gazette Méd., 1853, No. 7, 11, 22 and 23; and Scherer, in Canstatt's Jahresbericht, 1853, S. 118.

[3] Lehrbuch der Physiologischen Chemie, ii. 14, Leipz., 1850; or Amer. edit. of Dr. Day's translation by Dr. R. E. Rogers, i. 415, Philad., 1855.

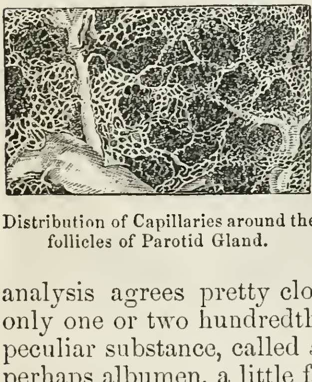
[4] Hecker's Wissenschaftliche Annalen, B. ii. H. i. § 32, 1835.

[5] Rullier and Raige-Delorme, art. Digestion, Dict. de Médecine, 2de édit., x. 300, Paris, 1835.

with the first mouthful of food. The average amount of the secretion in the twenty-four hours has not been considered to exceed four ounces. Messrs. Bidder and Schmidt,[1] however, estimate the probable amount for an adult at 1·40 kilogramme or between three and four pounds in the twenty-four hours.

According to Berzelius,[2] its constituents are—water, 992·2; peculiar animal matter, 2·9; mucus, 1·4; chlorides of potassium and sodium, 1·7; lactate of soda, and animal matter, 0·9; soda, 0·2. Drs. Bostock[3] and Thomas Thomson[4] think that the "mucus" of Berzelius resembles coagulated albumen in its properties. In the tartar of the teeth, which seems to be a sediment from the saliva, Berzelius found 79 parts of earthy phosphate; 12·5 of undecomposed mucus; 1 part of a matter peculiar to the saliva, and 7·8 of an animal matter soluble in chlorohydric acid. This animal matter, according to the microscopic experiments of M. Raspail,[5] is composed of deciduous fragments from the mucous membrane of the cavity of the mouth; and he considers, that the saliva is nothing more than an albuminous solution, mixed with different salts, that are capable of modifying more or less its solubility in water, and of shreds or layers of tissue. MM. Leuret and Lassaigne[6] analyzed *pure* saliva, obtained from an individual labouring under salivary fistula, and found it to contain,—water, mucus, traces of albumen, soda, chloride of potassium, chloride of sodium, carbonate and phosphate of lime; and Messrs. Tiedemann and Gmelin[7] affirm,—and their analysis agrees pretty closely with that of Van Setten[8]—that it has only one or two hundredths of solid matter, which are composed of a peculiar substance, called *salivary matter* or *ptyalin*, osmazome, mucus, perhaps albumen, a little fat containing phosphorus, and the insoluble salts—phosphate and carbonate of lime. Besides these, they detected the following soluble salts;—acetate, carbonate, phosphate, sulphate, sulphocyanate of potassa; and chloride of potassium. Treviranus[9] thought that the saliva contains a peculiar acid, probably combined with an alkali; but its chemical properties resemble the sulpho-cyanic acid so greatly, that according to Kastner[10] they may be taken for each other.

Fig. 154.



Distribution of Capillaries around the follicles of Parotid Gland.

As the result of numerous analyses, Dr. Wright[11] gives the following constituents of healthy saliva;—water, 988·1; ptyalin, 1·8; fatty

[1] Die Verdauungssäfte und der Stoffwechsel, S. 13, Mitau and Leipzig, 1852.
[2] Medico-Chirurgical Transactions, iii. 242.
[3] Physiol., ed. cit., p. 487.
[4] System of Chemistry, vol. iv.
[5] Nouveau Système de Chimie Organique, p. 454.
[6] Recherches, &c., sur la Digestion, p. 33, Paris, 1826.
[7] Recherches, &c., sur la Digestion, par Jourdan, Paris, 1827.
[8] De Salivâ ejusque Vi et Utilitate, Groning., 1837; cited in Brit. and For. Med. Rev., Jan., 1839, p. 236.
[9] Biologie, Band. iv. § 330.
[10] Ficinus, art. Speichel, in Pierer's Anat. Physiol. Real Wörterbuch, vii. 634, Altenb., 1827.
[11] London Lancet, Mar., 1842.

acid, ·05; chlorides of sodium and potassium, 1·4; albumen with soda, 0·9; phosphate of lime, 0·6; albuminate of soda, ·08; lactates of potassa and soda, ·07; sulphocyanide of potassium, ·09; soda, ·05; mucus with ptyalin, 2·6. It has also been carefully analyzed by Enderlin,[1] who concludes that, like the blood, it contains no lactate, carbonate, or acetate; but its alkaline reaction is owing to the tribasic phosphate of soda, which serves also as a solvent of the mucus and protein compounds. The analysis of the ashes obtained from a very large quantity afforded, in 100 parts:—

Tribasic phosphate of soda,	28·122
Chlorides of sodium and potassium,	61·93
Sulphate of soda,	2·315
Phosphate of lime, " magnesia, " iron,	5·509

Still more recently, human saliva has been analyzed by Jacubowitsch[2] and found to be composed as follows:—

Water,	999·16
Fixed residue,	4·84
Epithelium,	1·62
Organic matters,	1·34
Sulphocyanide of potassium,	0·06
Salts,	1·82

The salts consisted of phosphate of soda, 0·94; lime, 0·03; magnesia, 0·01; chlorides of potassium and sodium, 0·84.[3]

M. Lassaigne[4] examined the secretion from the parotid gland; and that from the submaxillary of the same animal. Both were transparent fluids, and possessed a slight alkaline reaction. That of the submaxillary was more viscid, and similar to mucus in consistence. The following was the quantitative analysis of the two. That of the parotid of the cow contained water, 990·74; mucus and soluble organic matters, 0·44; alkaline carbonates, 3·38; alkaline chlorides, 2·85; alkaline phosphates, 2·49; phosphate of lime, 0·10. That of the submaxillary contained water, 991·14; mucus, 1·73; soluble animal matters, 1·80; alkaline carbonates, 0·10; alkaline chlorides, 5·02; alkaline phosphate, 0·15; phosphate of lime, 0·06.[5]

Messrs. Tiedemann and Gmelin, and M. Donné,[6] found the saliva invariably alkaline, when the functions of the stomach were well executed. The last gentleman considered acidity of the saliva a diagnostic symptom of gastritis; and Dr. Robt. Thomson[7] observed the acid reaction in all cases of inflammation of the mucous and serous

[1] Annalen der Chemie und Pharmacie, Marz., 1844.

[2] De Salivâ, Dissert. inaugur. Med. Univers. Dorpatens.; cited by Scherer, in Canstatt and Eisenmann's Jahresbericht über die Forstchritte der Biologie im Jahre 1848, Erlang., 1849.

[3] G. Owen Rees, Art. Saliva, in Cyclop. of Anat. and Physiol., iv. 415, Lond., 1852.

[4] Journal de Chimie Médicale, p. 393; and Scherer, in Canstatt's Jahresbericht, S. 106, 1852.

[5] See on the whole subject of the Saliva, Bidder & Schmidt, Die Verdauungssäfte u. s. w. S. 1, Mitau und Leipzic, 1852.

[6] Archives Générales, Mai & Juin, 1835; and Histoire Physiologique et Pathologique de la Salive, Paris, 1836.

[7] Records of General Science, Dec., 1836.

membranes. With the view of testing these points, Mr. Laycock[1] instituted numerous experiments, and tabulated the results of no less than 567 observations. His deductions do not accord with those of M. Donné. They are as follows:—1. The saliva may be acid without apparent disease of the stomach, and when the person is in good health. 2. It is alkaline during different degrees of gastric derangement, as indicated by the tongue. 3. It may be alkaline, acid and neutral, when the gastric phenomena are the same; and, consequently, acidity of the saliva is not a diagnostic mark of gastric derangement; and, lastly, in general it is alkaline in the morning, and acid in the evening. In a more recent work M. Donné[2] accounts for the varying testimony of different observers in regard to the chemical reaction of the saliva, by the greater or less proportion of the mucus of the mouth contained in the specimens subjected to examination. In the normal state, he affirms, it is alkaline; but the mucus secreted by the mucous membrane of the mouth being acid, the mixed fluid, to which the name saliva is given, must necessarily vary according to the proportion of each.

When saliva is examined by the microscope, it presents, besides a considerable number of lamellæ of epithelium, globules in variable quantity, which, according to M. Mandl,[3] proceed partly from the muciparous glands of the mouth, and partly from the salivary glands. They cannot, however, be distinguished from each other.

As the salivary secretion forms a part in the processes preparatory to stomachal digestion, its uses have been detailed in the first volume of this work, to which the reader is referred. The view of MM. Bernard and Barreswil, and of Mialhe, that the saliva contains an active principle, analogous in its physical and chemical characters to diastase, as well as its action on amylaceous substances, is there described.

A soft, whitish or yellowish matter, of greater or less thickness, is constantly deposited on the teeth, which, unless attention is paid, accumulates, and sometimes adheres to them with great force, constituting hard and dry concretions, known—as already remarked—under the name of *tartar* or *tartar of the teeth.* Different views have existed in regard to its origin. Some have supposed it to be a secretion, others a deposition from the saliva, which is the most probable opinion; and others that it is an exhalation from the capillary vessels, to which the mucous membrane of diseased gums is liable. It has been affirmed by M. Mandl[4] to be a collection of calcareous skeletons of infusoria, agglutinated by means of dried mucus.

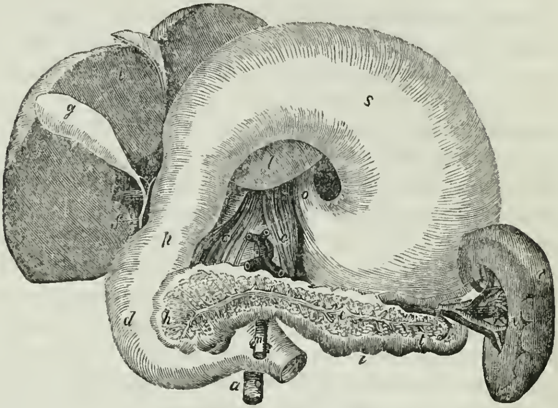
4. *Secretion of the Pancreas.*

The *pancreas* or *sweetbread*, (Fig. 155, *h*, *t*, *i*,) secretes a juice or humour called *succus pancreaticus*, *pancreatic juice.* Its texture resembles that of the salivary glands; and hence it has been called by some the *abdominal salivary gland.* It is situate transversely in the abdomen;

[1] Lond. Med. Gazette, Oct. 7, 1837. See, for a detailed account of the saliva, Dr. S. Wright, op. cit.
[2] Cours de Microscopie, p. 208, Paris, 1844.
[3] Manuel d'Anatomie Générale, p. 488, Paris, 1843.
[4] Gazette des Hôpitaux, 8 Août, 1843, p. 363.

behind the stomach; towards the concavity of the duodenum; is about six inches in length, and between three and four ounces in weight. From the results of six examinations, Dr. Gross[1] gives the following as its mean weight and dimensions:—Weight $2\frac{1}{2}$ ounces; length, 7 inches; breadth at the body and splenic extremity, $16\frac{1}{2}$ lines; breadth at the neck, 12 lines; at the head, 2 inches and 3 lines; thickness at the body, neck, and splenic extremity, 4 lines; thickness at the head, 8 lines. M. Bécourt found the average length of thirty-two to be 8 inches; and the weight between 3 and 4 ounces.[2] It is of a reddish-white colour, and firm consistence. Its excretory ducts terminate in one,—called *duct of Wirsung*,—which opens into the duodenum, at times separately from the ductus communis choledochus, but close to it; at others, confounded with, or opening into, it.[3] In the rabbit it opens several inches—35 centimètres—below it. According to M. Béraud[4] there are at all times two pancreatic ducts—the larger that already mentioned; the smaller proceeding from the summit of the head of the gland, and opening into the duodenum above the choledoch duct in man. This fact—he says—has been demonstrated by his own researches, as well as by those of M. Bernard, and is seen in the preparations in the museum of the "*École de Médecine*," made by MM. Verneuil, Boulard, Fano and himself.

Fig. 155.



In this figure, which is altered from Tiedemann, the Liver and Stomach are turned up to show the Duodenum, the Pancreas, and the Spleen.

l. The under surface of the liver. *g*. Gall-bladder. *f*. The common bile-duct, formed by the union of a duct from the gall-bladder, called the cystic duct, and of the hepatic duct coming from the liver. *o*. The cardiac end of the stomach, where the œsophagus enters. *s*. Under surface of the stomach. *p*. Pyloric end of stomach. *d*. Duodenum. *h*. Head of pancreas; *t*, tail; and *i*, body of that gland. The substance of the pancreas is removed in front, to show the pancreatic duct (*e*) and its branches. *r*. The spleen. *v*. The hilus, at which the bloodvessels enter. *c*. Crura of diaphragm. *n*. Superior mesenteric artery. *a*. Aorta.

The amount of fluid secreted by the pancreas does not seem to be considerable. M. Magendie, in his experiments, was struck with the small quantity discharged. Frequently, scarcely a drop issued in half an hour; and, occasionally, a much longer time elapsed. Nor did he find that the flow, according to common opinion, and to probability, was more rapid whilst digestion was going on. It will be readily

[1] Elements of Pathological Anatomy, ii. 357, Boston, 1839.

[2] Recherches sur le Pancréas, ses Fonctions et ses Altérations Organiques, Thèse, Strasbourg, 1830, cited by Mondière, Archives Générales de Médecine, Mai, 1836.

[3] Magendie, Précis Elémentaire, i. 462; and J. P. Mondière, op. cit.

[4] Manuel de Physiologie de l'Homme, p. 173, Paris, 1853.

understood, therefore, that it cannot be an easy task to collect it. De Graaf[1] affirms, that he succeeded, by introducing into the intestinal end of the excretory duct a small quill, terminating in a phial fixed under the belly of the animal. M. Magendie[2] states, that he tried this plan several times, but without success; and he believes it to be impracticable. The plan he adopts is to expose the intestinal orifice of the duct; to wipe the surrounding mucous membrane with a fine cloth, and as soon as a drop of the fluid oozes to suck it up by means of a *pipette* or small glass tube. In this way, he collected a few drops, but never sufficient to undertake a satisfactory analysis. Messrs. Tiedemann and Gmelin[3] made an incision into the abdomen; drew out the duodenum, and a part of the pancreas; and, opening the excretory duct, inserted a tube into it; and a similar plan was adopted successfully on a horse by MM. Leuret and Lassaigne.[4] M. Bernard's plan is to make an incision into the right hypochondrium, draw out the duodenum with a part of the pancreas, pass a double ligature around the duct, and fix into it a silver tube, the extremity of which, outside the abdomen, is attached to a small India-rubber bag, into which the fluid flows in large pearl-shaped drops.[5]

The difficulty experienced in collecting any quantity is a probable cause of some of the discrepancy amongst observers, regarding its sensible and chemical properties. Certain of the older physiologists affirm that it is acidulous and saline; others, that it is alkaline.[6] The majority of those of the present day compare it with saliva, and affirm it to be inodorous, insipid, viscid, limpid, and of a bluish white colour. The latest experimenters by no means agree with each other. According to M. Magendie, it is of a slightly yellowish hue, saline taste, devoid of smell, occasionally alkaline, and partly coagulable by heat. MM. Leuret and Lassaigne found that of the horse—of which they obtained three ounces,—to be alkaline, and composed of 991 parts of water in 1000; an animal matter, soluble in alcohol; another, soluble in water; traces of albumen and mucus; free soda; chloride of sodium; chloride of potassium; and phosphate of lime. In their view, consequently, the pancreatic juice strongly resembles saliva. Messrs. Tiedemann and Gmelin succeeded in obtaining upwards of two drachms of the juice in four hours; and, in 100 parts, found from five to eight of solid parts. These consisted of osmazome; a matter which became red by chlorine; another analogous to casein, and probably associated with salivary matter; much albumen; a little free acid, probably acetic; acetate, phosphate, and sulphate of soda, with a little potassa; chloride of potassium, and carbonate and phosphate of lime;—so that, according to these gentlemen, the pancreatic juice differs from saliva in containing a little free acid, whilst saliva is alkaline; much albumen, and matter resembling casein; but little mucus and salivary matter, and no sulphocyanate of potassa. In an examination by M. Blondlot[7] of three or

[1] Tract. de Pancreat., Ludg. Bat., 1761; and Haller, Elem. Physiol., lib. xxii. sect. 8, Bern., 1764.

[2] Précis, &c., ii. 462. [3] Recherches, &c., i. 41. [4] Ibid., p. 49.

[5] Béraud, op. cit., p. 173, Paris, 1853.

[6] Haller, op. cit.; and Seiler, art. Pancreas, Pierer's Anat. Physiol. Real Wörterb., Band vi. 100, Altenb., 1825.

[7] Traité Analytique de la Digestion, p. 124, Paris, 1844.

four grammes of fluid, obtained from the duct of a large dog, he found no evidences of albumen, when he passed an electric current through it. He, also, holds it to be of the same nature as saliva.

The following is the result of a recent analysis: water, 94·28; pancreatin,—a matter coagulable by heat;[1] mucus; carbonate of soda; chlorides of sodium and potassium; and phosphate of lime, 8·72; total, 100·00. The pancreatin gives to the pancreatic secretion its special properties.[2]

The precise use of the pancreatic juice in digestion—as we have previously seen—is not determined. Brunner[3] removed almost the whole pancreas from dogs, and tied and cut away portions of the duct; yet they lived apparently as well as ever. The secretion, therefore, cannot be indispensable. Its main uses seem to be to favour the absorption of oleaginous matters.

5. *Secretion of the Liver.*

The biliary secretion is, also, a digestive fluid, and has been treated of in the appropriate place. The mode, however, in which the process is effected, has not yet been investigated. The apparatus consists of the *liver*, which accomplishes the formation of the fluid; the *hepatic duct*—the excretory channel, by which the bile is discharged; the *gall-bladder*, in which a portion of the bile is retained for a time; the *cystic duct*—the excretory channel of the gall-bladder; and the *ductus communis choledochus* or *choledoch duct*, formed by the union of the hepatic and cystic ducts, which conveys the bile immediately into the duodenum.

The *liver* is the largest gland in the body; situate in the abdomen beneath the diaphragm, above the stomach, the arch of the colon, and the duodenum; filling the whole of the right hypochondrium, and more or less of the epigastrium, and fixed in its situation by duplicatures of the peritoneum, called *ligaments of the liver*. The weight of the human organ is generally, in the adult, about three or four pounds. Some make the average about five pounds; but this is a large estimate. Of 60 male livers weighed, Dr. John Reid[4] found the average weight to be 52 oz. 12½ dr.; and of 25 female, 45 oz. 3½ dr. In disease, however, it sometimes weighs twenty or twenty-five pounds; and, at other times, not as many ounces. Its shape is irregular, and it is divided into three chief lobes, the *right*, *left*, and *lobulus Spigelii*. Its upper convex surface every where touches the arch of the diaphragm. The lower concave surface corresponds to the stomach, colon, and right kidney. On the latter surface, two *fissures* are observable,—the one passing from before to behind, and lodging the umbilical vein in the fœtus—called *horizontal sulcus* or *fissure*, *great fissure* or *fossa umbilicalis*; the other cutting the last at right angles, and running from right to left, by which different nerves and vessels proceed to and from the liver, and called *principal fissure*, or *sulcus transversus*.

[1] Béraud, op. cit., p. 179.
[2] Robin et Verdeil, Traité de Chimie Anatomique, &c., iii. 345, Paris, 1853.
[3] Experimenta nova circa Pancreas, Amstel., 1683; and J. T. Mondière, op. cit.
[4] Lond. and Edinb. Monthly Journ. of Med. Science, April, 1843, p. 323.

The liver itself is composed of the following anatomical elements: 1. The *hepatic artery*, a branch of the cœliac, which ramifies minutely through the substance of the organ. The minuter branches of this vessel are arranged somewhat like the hairs in a painter's brush, and have hence been called *penicilli* of the liver. Mr. Kiernan[1] believes, that the blood, which enters the liver by the hepatic artery, fulfils three functions:—it nourishes the organ; supplies the excretory ducts with mucus; and, having fulfilled these objects, becomes venous; enters the branches of the portal veins, and not the radicles of the hepatic, as usually supposed, and as still maintained by J. Müller and others; and contributes to the secretion of bile. 2. The *vena porta*, which, we have elsewhere seen, is the common trunk of the veins of the digestive organs and spleen. It divides like an artery, its branches accompanying those of the hepatic artery. Where it lies in the transverse fissure, it is of great size, and has hence been called *sinus venæ portæ*.

The possession of two vascular systems, containing blood, is peculiar, perhaps, to the liver, and has been the cause of difference of opinion, with regard to the precise fluid—arterial or venous—from which the bile is derived. According to Mr. Kiernan, the portal vein fulfils two functions: it carries the blood from the hepatic artery, and the mixed blood to the coats of the excretory ducts. It has been called *vena arteriosa*, because it ramifies like an artery, and conveys blood for secretion: but, as Mr. Kiernan has observed, it is an *arterial vein*, in another sense, as it is a vein to the hepatic artery, and an artery to the hepatic vein. 3. The *excretory ducts* or *biliary ducts*. These are presumed to arise from acini, communicating, according to some, with the extremities of the vena porta; according to others, with radicles of the hepatic artery; whilst others have considered, that the radicles of the hepatic ducts have blind extremities, and that the capillary bloodvessels, which secrete the bile, ramify on them. This last arrangement of the biliary apparatus was well shown in an interesting case, which fell under the care of Professor Hall, in the Baltimore Infirmary, and was examined after death in the author's presence. The particulars have been detailed, with some interesting remarks, by Professor Geddings.[2] In this case, in consequence of cancerous matter obstructing the ductus communis choledochus, the whole excretory apparatus of the liver was enormously distended; the common duct was dilated to the size of the middle finger: at the point where the two branches that form the hepatic duct emerge from the gland, they were large enough to receive the tip of the middle finger; and as they were proportionally dilated to their radicles in the intimate tissue of the liver, their termination in a blind extremity was clearly exhibited. These blind extremities were closely clustered together, and the ducts, proceeding from them, were seen to converge, and terminate in the main trunk for the corresponding lobe. At their commencement, the excretory ducts are termed *pori biliarii*. These ultimately form two or three large trunks, which issue from the liver by the transverse fissure, and end in the *hepatic duct*. 4. *Lymphatic vessels*. 5. *Nerves*, in small number, compared with the size

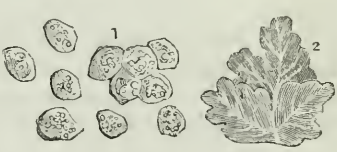
[1] Philosophical Transactions for 1833, p. 711.

[2] North American Archives of Medical and Surgical Science, for June, 1835, p. 157.

of the organ, some proceeding from the eighth pair; but the majority from the solar plexus, which follow the course and divisions of the hepatic artery. 6. *Supra-hepatic veins* or *venæ cavæ hepaticæ*, which arise in the liver by imperceptible radicles, communicating, according to common belief, with the final ramifications of both the hepatic artery and vena portæ; according to Mr. Kiernan occupying the centre of the lobules, and hence termed *intralobular veins*—*venulæ intralobulares* seu *centrales.* They return the superfluous blood, carried to the liver by these vessels, by means of two or three trunks, and six or seven branches, which open into the vena cava inferior. These veins generally pass, in a convergent manner, towards the posterior margin of the liver, and cross the divisions of the vena portæ at right angles. 7. The remains of the umbilical vein, which, in the fœtus, enters at the horizontal fissure. This vein, after respiration is established, becomes converted into a ligamentous substance, called, from its shape, *ligamentum rotundum* or *round ligament.* It is difficult to describe the parenchyma or substance formed by these anatomical elements; and although the term *liver-coloured* is used in common parlance, it is not easy to say what are the ideas attached to it.

The views of Mr. Kiernan in regard to the intimate structure of the liver, which have been embraced by so many anatomists, may be understood by the accompanying illustrations, taken from his communications on the subject. The acini, to which allusion has been made, are termed by him *lobules.* Fig. 156, 1, exhibits some of the cells of which the lobules are composed, seen under a magnifying power of 200 diameters. 2, represents a longitudinal section of a lobule with ramifications of the hepatic vein: and Fig. 157, the connexion of the lobules with the same vein;—the centre of each being occupied by a venous twig—or intralobular vein. Fig. 158 represents the lobules as seen on the surface of the liver when divided transversely. In this, 2, exhibits the interlobular spaces; 3, interlobular fissures; 4, intralobular veins occupying the centres of the lobules; and 5, smaller veins terminating in the central veins. Fig. 159 is a similar section of three lobules, showing the arrangement of the two principal systems of bloodvessels; 1, 1, intralobular veins; and 2, 2, interlobular plexus formed by branches of the vena porta. Fig. 160 represents a horizontal section of two superficial lobules, showing the *interlobular plexus of biliary ducts:* 1, 1, intralobular veins; 2, 2, trunks of biliary ducts, proceeding from the plexus which traverses the lobules; 3, interlobular tissue; and 4, parenchyma of the lobules. The interlobular biliary ducts ramify upon the capsular surface of the lobules; and then enter

Fig. 156.



Lobules of Liver.

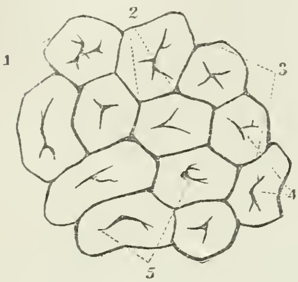
Fig. 157.

Connexion of Lobules of Liver with Hepatic Vein.

1. Hepatic vein. 2, 2, 2. Lobules, each containing an intralobular or hepatic twig.

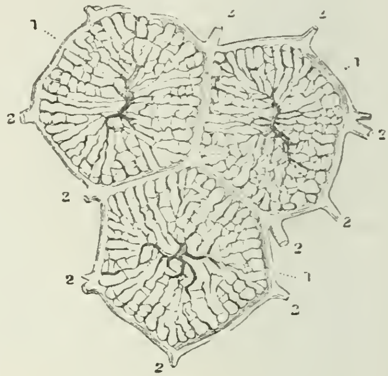
their substance and are supposed to subdivide into minute branches, which by anastomoses with each other form the reticulated plexus depicted in Fig. 160, called by Mr. Kiernan the *lobular biliary plexus.*

Fig. 158.



Transverse Section of Lobules of the Liver.

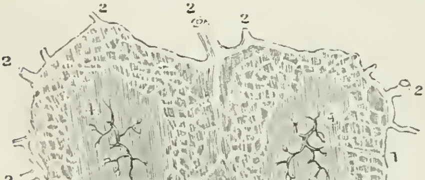
Fig. 159.



Horizontal Section of three Superficial Lobules, showing the two principal Systems of Bloodvessels.

It is from this arrangement of the bloodvessels and biliary ducts, that Mr. Kiernan infers that bile must be secreted from the portal vessels;—the intralobular ramifications of the hepatic veins conveying back to the heart the blood which has been inservient to the secretion. The views of Mr. Kiernan have been generally adopted by anatomists. Wagner, however, whilst he regards the beautiful figures and descriptions of Mr. Kiernan as the best he has seen, asserts, that they very certainly also include many mistakes; whilst Krause "combats the views of Kiernan, holding them to be hypothetical;"[1] and E. H. Weber[2] and Krukenberg oppose them. The chief point, according to Mr. Paget, in which these gentlemen differ from Mr. Kiernan, is in denying that the component parts of the liver are arranged in lobules. They, with Henle and Mr. Bowman, describe the capillary networks as solid,—that is as extending uniformly through the liver. They, also, deny the existence of fibro-cellular partitions dividing the liver into lobules as maintained by Mr. Kiernan and J. Müller;[3] and even the existence of more fibro-areolar tissue than serves to invest the larger vessels, &c., of the organ. They likewise deny

Fig. 160.

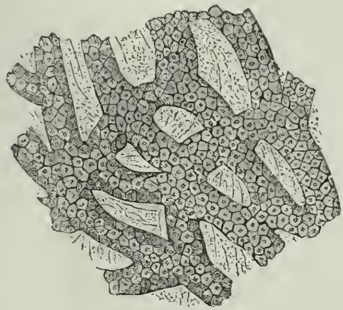


Horizontal Section of two Superficial Lobules, showing Interlobular Plexus of Biliary Ducts.

[1] Wagner, Elements of Physiology, by R. Willis, § 195, Lond., 1842.
[2] Müller's Archiv., 1844, Heft 3 and 4. [3] Ibid.

that there are any such interlobular veins and fissures as Mr. Kiernan describes, and state, that the smaller branches of these veins communicate by branches only just larger, if at all larger, than capillaries.[1]

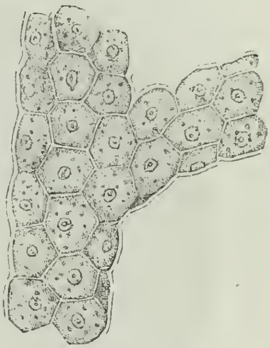
Fig. 161.



A small portion of a Lobule highly magnified.

The secreting cells are seen within the tubes, and in the interspaces of the latter the fibrous tissue is represented.

Fig. 162.

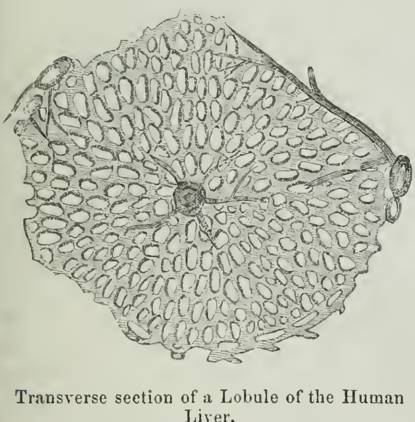


Portion of a Biliary Tube, from a fresh Human Liver, very highly magnified.

The secreting cells may be noticed to be polygonal from mutual pressure.

Histologically considered, the liver may be regarded as consisting of ramifications of excretory ducts, surrounded by bloodvessels, which afford the materials for secretion,—and of cells which elaborate it, but as respects the precise arrangement of the cells anatomists are not wholly in accordance. Dr. Leidy[2] affirms, that they line the inner surface of the tubuli that form the biliary plexus of Kiernan; that they are irregularly angular or of a polygonal shape, owing to their pressing upon each other; and contain a fine granular matter, oil globules, a granular nucleus and transparent nucleolus,—the oil globules, under special circumstances of diet and

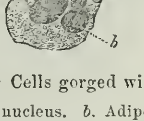
Fig. 163.



Transverse section of a Lobule of the Human Liver,

Showing the reticular arrangement of its parenchyma, with some of the branches of the hepatic vein in the centre, and those of the portal vein at the periphery.

Fig. 164.



Hepatic Cells gorged with Fat.

a. Atrophied nucleus. *b.* Adipose globules.

[1] See, on all this subject, Professor Theile, art. Leber, Wagner's Handwörterbuch der Physiologie, 9te Lieferung, S. 308, Braunschweig, 1845.

[2] American Journal of the Medical Sciences, p. 1, Jan., 1848; and Quain's edition of Quain and Sharpey's Human Anatomy, ii. 487, Philad., 1849.

disease, experiencing considerable increase. Dr. C. Handfield Jones[1] has, however, maintained, that the ramifications of the hepatic ducts

Fig. 165.

Minute Portal and Hepatic Veins and Capillaries.

a, a. Twigs of the portal vein. *d.* Twig of the hepatic vein. *b.* Intermediate capillaries.

Fig. 166.

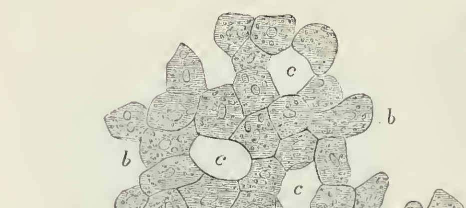


Diagram of the arrangement of the cellular parenchyma, *b, b,* of the human liver, with reference to the radicles of the interlobular ducts, *a, a,* and the vascular spaces, *c, c.*

do not enter the lobules as affirmed by Mr. Kiernan, but are confined to the interlobular spaces,—the substance of the lobules being composed of secreting parenchyma and bloodvessels; and that the action of the liver seems to consist in the transmission of the bile, as it is formed, from cell to cell, until it arrives in the neighbourhood of the excretory ducts by which it is absorbed.[2]

A similar view is embraced by Kölliker,[3] and in the last edition of his work Dr. Carpenter[4] states, that whilst in

[1] Philosophical Transactions, Pt. i., for 1849. See, also, Ibid., for 1846 and 1853.

[2] C. L. J. Backer, De Structurâ Subtiliori Hepatis Sani et Morbosi, p. 19, Traieet. ad Rhemm., 1845.

[3] Mikroskopische Anatomie, ii. 221, Leipzig, 1852: and Amer. translation of his Human Histology, by Dr. Da Costa, p. 535, Philad., 1854.

[4] Principles of Human Physiology, p. 372, note, Philad., 1855.

former editions he had embraced the view of the histology of the liver laid down by Retzius, Leidy, and others, farther inquiry had satisfied him that "the view of the compound nature of the hepatic structure, which Dr. C. Handfield Jones was the first to propound, and which harmonizes with Prof. Kölliker's account of its structure is really the correct one:"—"this view," he adds, "being strikingly confirmed and illustrated by the parallel order of anatomical and physiological facts presented by the vascular glands."[1]

Perhaps the best mode, according to Dr. Budd,[2] to get a general idea of the structure of the liver is to examine under the microscope, —*first*, a thin slice of liver, in which the portal and hepatic veins are thoroughly injected; and *secondly*,—a small particle taken from the lobular substance of a fresh liver, in which the bloodvessels are empty, as in an animal killed by bleeding. Figure 165, from a specimen by Mr. Bowman, represents, on a magnified scale, a small branch

Fig. 167.

Lobules of the Liver magnified.

a, a, a. Minute twigs of the portal vein. *b, b, b.* Capillaries immediately springing from them, and serving with them to mark the outline of the lobules. *d, d, d.* Capillaries in the centre of the lobules, injected through the hepatic vein. *e, e.* Places at which the size injected into the portal vein has met that injected into the hepatic vein, so that all the intermediate capillaries are coloured and conspicuous. *l, l.* Centres of lobules into which the injection has not passed through the hepatic vein.

of the hepatic vein, two or three branches of the portal vein, and the intermediate capillaries. The capillaries appear to have nearly the

[1] For recent views of the histology of the liver differing from those of Kölliker and C. Handfield Jones, see Proceedings of the Royal Society, June, 1855; and Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 528. He considers that the cells of the ducts stand in relation to the hepatic cells as the columnar epithelium lining the stomach tubes does to the secretory cells at the bottom of them.

[2] On Diseases of the Liver, 2d Amer. edit., p. 120, Philad., 1853.

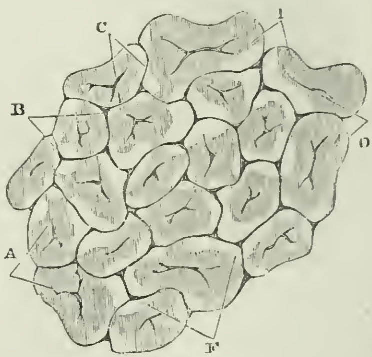
same relation to the branches of the portal vein as they have to those of the hepatic. It is difficult to tell, from this specimen, which branch is portal and which hepatic,—the smaller branches of both being, as it were, hairy with capillaries springing directly from them on every side, and forming a close and continuous network. Dr. Budd thinks, that the injected preparations of Mr. Bowman show clearly, that the opinion of Malpighi, Kiernan, Müller, and others, that the lobules are isolated from each other, each being invested by a layer of areolar tissue, is erroneous; and that the lobules are not distinct, isolated bodies, but merely small masses, tolerably defined by the ultimate twigs of the portal vein, and the injected or uninjected capillaries immediately contiguous to them. The lobules, according to Dr. Budd, appear only as distinct isolated bodies when seen by too low a magnifying power to clearly distinguish the capillaries. The real nature of the lobules, and the manner in which they are formed, will perhaps be better understood, he thinks, by reference to the illustration, (Fig. 167,) for which he expresses his indebtedness to Mr. Bowman. It represents, on a magnified scale, six lobules of the liver, and was made from a drawing under the microscope of a section of the liver of a cat, partially injected through the portal vein, and also through the hepatic.

Mr. Kiernan has deduced interesting pathological inferences from the anatomical arrangement of the liver which he conceives to exist;

Fig. 168.

First Stage of Hepatic Venous Congestion.

Fig. 169.



Second Stage of Hepatic Venous Congestion.

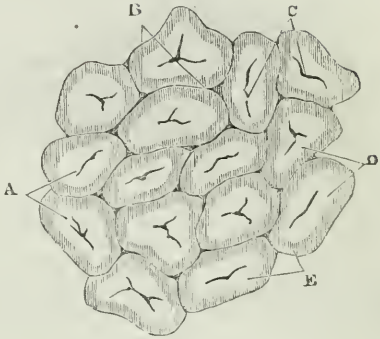
thus, he considers that the lobules may be congested by accumulation of blood in the hepatic or in the portal venous system; which may be detected by a minute inspection of the lobules. The precise causes of this are referred to in another work.[1] The accompanying illustrations will be sufficient here. Fig. 168 represents the lobules in the *first stage* of what he terms *hepatic venous congestion* or congestion of the terminations of the hepatic vein: 2, the interlobular spaces and fissures. In Fig. 169, the lobules are in the second stage of congestion. B and C, the interlobular spaces; D, congested intralobular or hepatic veins; I, congested patches extending to the circumference of the

[1] Practice of Medicine, 3d edit., vol. ii. chap. 3, Philad., 1848.

lobules; F, uncongested portions. In Fig. 170, the lobules are in a state of *portal venous congestion;* not a common occurrence. It has been seen by Mr. Kiernan in children only.

The view of Mr. Kiernan has been held to explain also the diversity of the statement of anatomists as to the relative position of the *red* and *yellow* substances, which have been considered to compose the liver: the red is the congested portion of the lobules, whilst the yellow is the non-congested portion in which the biliary plexus appears more or less distinctly.

Fig. 170.

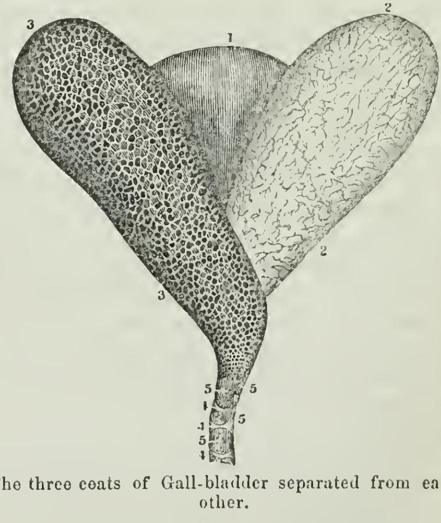


Portal Venous Congestion.

B. Interlobular spaces and fissures. C. Intralobular veins. D. Anæmic portions. E. Congested portions.

The liver has two coats;—the outer, derived from the peritoneum, which is very thin, transparent, easily lacerable, and vascular, and is the seat of the secretion effected by serous membranes in general. It does not cover the posterior part, or the excavation for the gall-bladder, the vena cava, or the fissures in the concave surface of the liver. The inner coat is the proper membrane of the liver. It is thin, but not easily torn, and covers not only every part of the surface of the liver, but the large vessels that are proper to the organ. The condensed areolar substance,—which unites the sinus of the vena porta and its two great branches, the hepatic artery, common biliary duct, lymphatic glands, lymphatic vessels, and nerves in the transverse fossa or fissure of the liver,—was described by Glisson as a capsule; and hence has been called *capsule of Glisson.* It connects the various anatomical elements of the liver together.

Fig. 171.



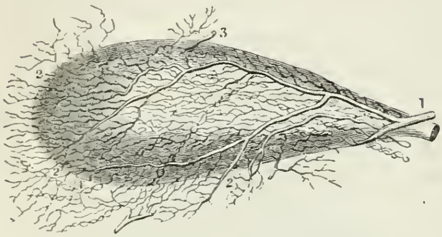
The three coats of Gall-bladder separated from each other.

1. External or peritoneal coat. 2. Areolar coat with its vessels injected. 3. Mucous coat covered with wrinkles. 4, 4. Valves, formed by this coat in the neck of gall-bladder. 5, 5. Orifices of mucous follicles at this point.

The *gall-bladder* is a small membranous pouch of a pyriform shape, situate at the inferior and concave surface of the liver to which it is attached; and above the colon and duodenum. A quantity of bile is usually found in it. It is not met with in all animals; is wanting in the elephant, horse, stag, camel, rhinoceros, and goat;

in certain of the cetacea; in some birds, as the ostrich, pigeon, and parrot; and is occasionally so in man. No traces of it are met with in the invertebrata. It may be looked upon as a dilatation of the gall-ducts, and adapted for the reception and retention of bile. Its largest part or *fundus* is turned forwards; and, when filled, frequently projects beyond the anterior margin of the liver. Its narrowest portion, cervix or neck, is turned backwards, and terminates in the cystic duct. Externally, it is partly covered by the peritoneum, which attaches it to the liver, and to which it is, moreover, adherent by areolar tissue and vessels. Internally, it is rugous; the folds being reticulated, and appearing somewhat like the cells of a honeycomb.

Fig. 172.



Gall-bladder distended with Air, and with its Vessels injected.

1. Cystic artery. 2. Branches of it which supply the peritoneal coat of the liver. 3. Branch of the hepatic artery which goes to gall-bladder. 4. Lymphatics of gall-bladder.

Anatomists have differed with regard to the number of coats proper to the gall-bladder. Some have described two only;—the peritoneal and mucous: others have added an intermediate areolar coat; whilst others have reckoned four:—a peritoneal,—a thin stratum of muscular fibres passing in different directions, and of a pale colour,—an areolar coat, in which a number of bloodvessels is situate, and an internal mucous coat. The existence of the muscular coat has been denied by perhaps the generality of anatomists; but there is reason for believing in its existence. Kölliker[1] affirms, that there is, between its peritoneal covering and the abundant subserous connective tissue, a delicate layer of muscles, whose fibre cells take more particularly a longitudinal and a transverse direction and present only indistinct nuclei. Amussat saw muscular fibres distinctly in a gall-bladder dilated by calculi; and Dr. Monro (Tertius),[2] Professor of Anatomy in the University of Edinburgh, asserts, that he has seen it contract, in a living animal, for half an hour, under mechanical irritation, and assume the shape of an hour-glass. The mucous coat forms the rugæ to which we have already alluded. In the neck, and beginning of the cystic duct, there are from three to seven—sometimes twelve—semilunar duplicatures, which retard the flow of any fluids inwards or outwards. These are sometimes arranged spirally, so as to form a kind of valve, according to M. Amussat.[3]

On the inner surface of the gall-bladder, especially near its neck, numerous follicles exist, the secretion from which is said to fill the gall-bladder, when that of the bile has been interrupted by disease, as in yellow-fever, scirrhus of the liver, &c. The *hepatic duct* is the com-

[1] Mikroskopische Anatomie, ii. 230, Leipzig, 1852; and Amer. edit. by Dr. Da Costa, p. 538, Philad., 1854.

[2] Elements of the Anatomy of the Human Body, Edinb., 1825.

[3] Magendie, Précis, &c., ii. 464.

mon trunk of all the excretory vessels of the liver; and makes its exit from that organ by the transverse fissure. It is an inch and a half in length, and about the diameter of an ordinary writing-quill. It is joined, at a very acute angle, by the duct from the gall bladder—*cystic duct*—to form the ductus communis choledochus. The cystic duct is about the same length as the hepatic. The *ductus communis choledochus* is about three, or three and a half inches long. It descends behind the right extremity of the pancreas, through its substance; passes for an inch obliquely between the coats of the duodenum, diminishing in diameter; and ultimately terminates by a yet more contracted orifice on the inner surface of the intestine, at the distance of three or four inches from the stomach. The structure of all these ducts is the same. The external coat is thick, dense, strong, and generally supposed to be of an areolar character; the inner is a mucous membrane, like that which lines the gall-bladder. A fibrous and a mucous layer, according to Kölliker,[1] can be readily distinguished in the ductus communis choledochus and the cystic duct; the mucous layer containing a few muscular fibre-cells; but, on the whole, so sparingly, that these ducts cannot—he considers—be said to possess any special muscular coat.

The secretion of bile is probably effected like that of other glandular organs; modified, of course, by the peculiar structure of the liver. We have seen, that the organ differs from every other secretory apparatus, in having two kinds of blood distributed to it;—arterial by the hepatic artery; and venous by the vena porta. A question has consequently arisen—from which of these is the bile formed? Anatomical inspection does not positively settle the question; for whilst—as has been seen—it is maintained by Müller and others, that the ultimate termination of the capillaries is in the hepatic veins; others, with Kiernan, believe that they communicate with the portal system; and if this arrangement were demonstrated, we should be compelled to ascribe the secretion to the mixed blood, which flows in the interlobular veins. But this point of hepatic histology is not determined. Argument is all that can be adduced on one side or the other. The most common and the oldest opinion is, that the bile is separated from the blood of the vena porta; and the chief reasons brought forward in favour of the belief, are the following: *First.* The blood of the portal system is better adapted than arterial blood for the formation of bile, on account of its having, like all venous blood, more carbon and hydrogen, which are necessary for the production of a humour as fat and oily as the bile; and, as the experiments of Schultz[2] and others have proved, that portal blood contains more fat than that of other veins and arteries, it has been imagined, by some, that the blood, in crossing the omentum, becomes loaded with fat. *Secondly.* The vena porta ramifies in the liver after the manner of an artery, and evidently communicates with the secretory vessels of the bile. *Thirdly.* It is larger than the hepatic artery; and more in proportion to the size of the liver; the hepatic artery seeming to be merely for the nutrition of the liver, as the bronchial artery is for that of the lung.

[1] Op. cit.
[2] Rust's Magazine, B. xliv.; or Gazette Médicale, Aug. 15, 1835.

In answer to these positions, it has been argued. *First.* That there seems to be no more reason why the bile should be formed from venous blood than other fatty and oleaginous humours,—marrow and fat for example,—which are derived from arterial blood. It is asked, too, whether, in point of fact, the blood of the vena porta is more rich in carbon and hydrogen? and whether there be a closer chemical relation between bile and the blood of the vena porta, than between fat and arterial blood? The notion of the absorption of fat from the omentum, it is properly urged, is totally gratuitous. *Secondly.* The vena porta does not exist in the invertebrated animals; and yet, in a number of them, there is an hepatic apparatus, and a secretion of bile. *Thirdly.* Admitting that the vena porta is distributed to the liver after the manner of an artery; is it clear, it has been asked, that it is inservient to the biliary secretion? *Fourthly.* If the vena porta be more in proportion to the size of the liver than the hepatic artery, the latter appears to bear a better ratio to the quantity of bile secreted: and, *Lastly.* It is clear, as has been shown in another place, that the liver has other important functions connected with the portal system, as the admixture of heterogeneous liquids absorbed from the intestinal canal, and their assimilation.

In the absence of accurate knowledge derived from direct experiment, physiologists have usually embraced one or other of these exclusive views. The generality, as we have remarked, assign the function to the vena porta. Bichat, J. Müller, and others, ascribe it to the hepatic artery. M. Broussais[1] thinks it probable, that the blood of the vena porta is not foreign to the formation of bile, since it is confounded with that of the hepatic artery in the parenchyma of the liver; "but to say with the older writers, that the bile can only be formed from venous blood, is, in our opinion," he remarks, "to advance too bold a position, since the hepatic arteries send branches to each of the glandular acini, that compose the liver." M. Magendie likewise concludes, that nothing militates against the idea of both kinds of blood participating in the secretion; and that it is supported by anatomy, as injections prove, that all the vessels of the liver,—arterial, venous, lymphatic, and excretory,—communicate with each other. Mr. Kiernan, as we have seen, considers that the blood of the hepatic artery, after having nourished the liver, is inservient to the secretion, but not until it has become venous, and entered the portal veins. He,—with all those that coincide with him in the morphological arrangement of the liver,—denies that there is any communication between the ducts and blood-vessels; and asserts, that if injections pass between them, it is owing to the rupture of the coats of the vessels. Experiments on pigeons, by M. Simon,[2] of Metz, showed, that when the hepatic artery was tied, the secretion of bile continued, but that if the portal and hepatic veins were tied, no trace of bile was subsequently found in the liver. It would thence appear, that in these animals the secretion of bile takes place from venous blood. But inferences from the ligature of those vessels have been very discordant. In two cases, in which Mr. Phillips

[1] Traité de Physiologie, &c., translation by Drs. Bell and La Roche, 3d edit., p. 456, Philad., 1832.

[2] Edinburgh Medical and Surgical Journal, xc. 229.

tied the hepatic artery, the secretion of bile was uninterrupted, yet the same thing was observed in three other cases, in which the ligature was applied to the trunk of the vena porta.

The view, that ascribes the bile to the hepatic artery, has always appeared to the author the most probable. It has all analogy in its favour. There has been no disputed origin as regards the other secretions, excepting, of late, in the case of the urinary. All proceed from arterial blood; and function sufficient, we have seen, can be assigned to the portal system, without conceiving it to be concerned in the formation of bile. We have, moreover, morbid cases, which would seem to show that bile can be formed from the blood of the hepatic artery. Mr. Abernethy[1] met with an instance, in which the trunk of the vena porta terminated in the vena cava; yet bile was found in the biliary ducts. A similar case is given by Mr. Lawrence;[2] and Professor Monro[3] details a case communicated to him by the late Mr. Wilson, then of the Windmill Street School, in which there was reason to suppose, that the greater part of the bile had been derived from the hepatic artery. The patient, a female, thirteen years old, died from the effects of an injury of the head. On dissection, Mr. Wilson found a large swelling at the root of the mesentery, consisting of several absorbent glands in a scrofulous state. Upon cutting into the mass, he accidentally observed a large vein passing directly from it into the vena cava inferior, which, on dissection, proved to be the vena porta; and on tracing the vessels entering into it, one proved to be the inferior mesenteric vein: and another, which came directly to meet it, from behind the stomach, proved to be a branch of the splenic vein, but somewhat larger, which ran upwards by the side of the vena cava inferior, and entered that vein immediately before it passes behind the liver. Mr. Wilson traced the branches of the trunk of the vessel corresponding to the vena porta sufficiently far in the mesentery and mesocolon to be convinced, that it was the only vessel that returned the blood from the small intestines, and from the cæcum and colon of the large intestines. He could trace no vein passing into the liver at the cavity of the porta; but a small one descended from the little epiploon, and soon joined one of the larger branches of the splenic vein. The hepatic artery came off in a distinct trunk from the aorta, and ran directly to the liver. It was much larger than usual. The greater size of the hepatic artery, in this case, would favour the idea, that the arterial blood had to execute some office, that ordinarily belongs to the vena porta. Was this the formation of bile? The case seems, too, to show, that bile can be formed from the blood of the hepatic artery.

Professor Gintrac[4] has published a case in which there was ossification with obliteration of the vena porta. The patient died of ascites. The liver was pale or whitish, and irregularly wrinkled or mammillated on its surface. The gall-bladder contained a medium quantity of thickish yellow bile. The biliary ducts were normal. The vena porta

[1] Philosophical Transactions, vol. lxxxiii.
[2] Medico-Chirurgical Transactions, iv. 174.
[3] Elements of Anatomy, Edinburgh, 1825.
[4] Cited in American Journal of the Medical Sciences, Oct., 1844, p. 476.

above the junction of the splenic and superior mesenteric veins was completely filled by an old clot, which adhered to the inner membrane. The clot was solid, and of a deepish black colour. At the same part of the vein several osseous plates were observed many lines in diameter, which were situate between the inner and middle coats of the vein, without having much adherence to either. All the abdominal veins that ended in these vessels were gorged with blood, and varicose. Professor Gintrac ascribed the ascites to the obliteration and ossification of the vena porta, and he considered the case to prove, that although obliteration of that vessel probably modified the secretion of bile, it did not prevent it altogether; but interfered materially with the nutrition of the liver. Hence, he inferred, that the blood of the vena porta contributes to the nutrition of the liver; but is not indispensable to the secretion of bile.

In Professor Hall's patient,[1] the vena porta and its bifurcation were completely filled with encephaloid matter, so that no blood could pass through it to the liver; the secretion of bile could not, consequently, have been effected through its agency. It has been presumed, however, that, in such cases, portal blood might still enter the liver through the extensive anastomoses, which Professor Retzius,[2] of Stockholm, found to exist between the abdominal veins. That gentleman observed, when he tied the vena porta near the liver, and threw a coloured injection into the portion below the ligature, that branches were filled, some of which, proceeding from the duodenum, terminated in the vena cava; whilst others, arising from the colon, terminated in the left emulgent vein. In subsequent investigations, he observed an extensive plexus of minute veins ramifying in the areolar tissue on the outer surface of the peritoneum, part of which was connected with the vena porta, whilst the other terminated in the system of the vena cava. In a successful injection, these veins were seen anastomosing very freely in the posterior part of the abdomen, with the colic veins, as well as with those of the kidneys, pelvis, and even the vena cava. The arrangement, pointed out by Retzius, accounts for the mode in which the blood of the abdominal venous system reaches the cava, when the vena porta is obliterated from any cause; and it shows the *possibility* of portal blood reaching the liver so as to be inservient to the biliary secretion, but does not, we think, exhibit the *probability*.

Since then, cases of obliteration of the vena porta have been recorded, in which the nutrition of the liver was materially impaired, so that the organ had become atrophied, whilst the secretion of bile persisted. Such a case is given by M. Raikem,[3] of Brussels. In this, the vein was entirely obliterated by clots of blood intimately adherent to its inner surface. The liver was smaller than usual; the gall-bladder contained a large quantity of serous bile of a yellowish and orange colour, and the cystic and hepatic ducts were filled with it. The trunk of the hepatic artery was three lines in diameter, and contained no clots

[1] Page 528.

[2] Ars Berättelse af Setterblad, 1835, S. 9; cited in Zeitschrift für die Gesammte Heilkunde, Feb., 1837, S. 251.

[3] Mémoires de l'Académie Royale de Médecine de Belgique, tom. i., Bruxelles, 1848; translated in the Edinb. Med. and Surg. Journal, April, 1850, p. 350.

of blood; and such was the case with the supra-hepatic veins. Whence M. Raikem concludes, that in the present state of physiological knowledge, there are reasons sufficiently conclusive for the opinion, that the hepatic artery is capable alone of furnishing to the liver the materials necessary for the secretion of bile, when the vena porta is obliterated to so great a degree as not to allow the blood to be conveyed through it to the organ; and, he asks, as the result of observations of numerous pathological cases, whether "it is indeed proved, as is generally believed, that the hepatic artery is alone charged with the function of nourishing the liver to the exclusion of the portal vein," when "we observe that the liver is atrophied in those in whom the portal vein has been entirely obliterated for a long time?" An additional case of the kind has been detailed by Dr. Craigie.[1] In this, the vein was found completely filled and distended by firm, yet compressible, elastic matter, as if the vessel had been injected, so that its diameter was fully one inch. Of the effects of this obliteration, the most remarkable, again, was the atrophy of the liver, which was not more than one-third of its usual size. A small quantity of light coloured bile was found in the gall-bladder, and during life the fæces had the usual colour. "M. Raikem," says Dr. Craigie, "has adverted to the notion so much favoured by various physiological speculators, that the hepatic artery is employed in maintaining the nutrition of the liver, while to the portal vein belongs the function of conveying to the gland the materials from which bile is to be prepared; and, to show its incompetency, has adduced several conclusive arguments. It is scarcely possible to conceive a stronger argument against it than is furnished by the facts of this case. The portal vein was completely obstructed, and no blood must for a long time have been conveyed through its branches into the gland. The liver is likewise very much reduced in size, not, indeed, uniformly and equally in all its parts, but still so much and so generally atrophied, that it is difficult to ascribe the diminution and wasting of parts to any other cause. The two circumstances, therefore, appear to stand in the relation of cause and effect." It is to be regretted that the history of this case is rendered imperfect by the circumstance, that "the state of the hepatic artery was not ascertained."

It would seem, then, that the portal system is not absolutely necessary to the formation of bile; yet a modern writer[2] considers it "a most puerile question" to ask whether the secretion can be effected from venous blood! "Had not," he adds, "secretion been destined to take place from the blood of the vena portarum, nature would not have been at the pains to distribute it through the liver; the peculiar arrangement is already an answer to the question; the end of it is, as I have said, to economise arterial blood." As before remarked, however, a sufficient function can be assigned to the portal system without supposing that it has any agency in the secretion of bile. Still, there is nothing inconsistent with the idea, that both kinds of blood may be inservient to the secretion. Mention has been made elsewhere, that

[1] Edinb. Med. and Surg. Journal, April, 1850, p. 512.

[2] Dr. R. Willis, London and Edinb. Monthly Journal of Med. Sciences, Sept., 1841, p. 628.

MM. Bouchardat and Sandras, having fed herbivorous animals on farinaceous substances, detected more dextrin, grape sugar, and lactic acid in the blood of the vena porta than in that of any other vessel; and that Trommer discovered grape sugar in the blood of the portal vein, but not in that of the hepatic veins of animals with whose food that substance had been mixed. Moreover, MM. Blondlot[1] and Chossat[2] found, that the administration of non-nitrogenous articles of food, especially of sugar, considerably increased the amount of bile secreted. On the other hand, however, Nasse found, that a diet of animal food induced a far more abundant secretion of bile in the dog than vegetable amylaceous food; yet an abundant addition of fat to the ordinary food of the animal occasioned a marked augmentation of the secretion. When cats, however, were fed on pure fat, Bidder and Schmidt[3] found, that they secreted no more bile than if they had been wholly deprived of food for the same time. An exclusive fatty diet does not, therefore, affect the biliary secretion.[4]

When bile is once formed in the tissue of the liver, it is received into the minute excretory radicles, whence it proceeds along the ducts until, from all quarters, it arrives at the hepatic duct. A difference of sentiment exists regarding the course of the bile from the liver and gall-bladder to the duodenum. According to some, it is constantly passing along the choledoch duct; but the quantity is not the same during digestion as at other times. In the intervals of digestion a part only of the bile attains the duodenum; the remainder ascends along the cystic duct, and is deposited in the gall-bladder. During digestion, however, not only the whole of the newly secreted bile arrives at the duodenum, but that which had been collected in the interval is evacuated into the intestine. In support of this view it is affirmed, that bile is always met with in the duodenum; and that the gall-bladder always contains more bile when abstinence is prolonged, and is empty immediately after digestion.

A great difficulty has been, to explain how the bile gets into the gall-bladder; and in what manner it is expelled from that reservoir. In many birds, reptiles, and fishes, the hepatic duct and cystic duct open separately into the duodenum; whilst ducts, called *hepato-cystic*, pass directly from the liver to the gall-bladder. In man, however, the only visible route, by which it can reach that reservoir, is by the cystic duct, the direction of which is retrograde; and, consequently, the bile in the erect attitude has to ascend against gravity. The spiral valve of M. Amussat has been presumed to act like the screw of Archimedes, and to facilitate the entrance of the refluent bile; but this appears to be imaginary. It is, indeed, impossible, to see any analogy between the corporeal and the hydraulic instrument. The arrangement of the termination of the choledoch duct in the duodenum has probably a more positive influence. The embouchure is the narrowest part of the duct; the ratio of its calibre to that of the hepatic duct

[1] Essai sur les Fonctions du Foie, p. 62, Paris, 1846.
[2] Gazette Médicale de Paris, Oct., 1843.
[3] Die Verdauungssäfte und der Stoffwechsel, S. 151, Mitau und Leipzig, 1852.
[4] Lehmann, Physiological Chemistry, translated from the German by Dr. Day; Amer. edit. by Dr. R. E. Rogers, i. 472, Philad., 1855.

having been estimated at not more than one to six, and to the calibre of its own duct as one to fifteen. This might render it impracticable for the bile to flow into the duodenum as promptly as it arrives at the embouchure; and, in this way collecting in the duct, it might reflow into the gall-bladder. M. Amussat, indeed, affirms, that this can be demonstrated on the dead body. By injecting water or mercury into the upper part of the hepatic duct, the injected liquid was found to issue both by the aperture into the duodenum, and by the upper aperture of the cystic duct into the gall-bladder.

With regard to the mode in which the gall-bladder empties itself during digestion, it is probably by a contractile action. We have seen, that it has not usually been admitted to possess a muscular coat, but that it is manifestly contractile. The chyme, as it passes into the duodenum, excites the orifice of the choledoch duct; this excitement is propagated along the duct to the gall-bladder, which contracts; but according to M. Amussat does not evacuate its contents suddenly; for the different planes of the spiral valve are applied against each other, and only permit the flow to take place slowly. This he found was the case in the dead body, when water was injected into the gall-bladder, and then passed out through the cystic duct. Other physiologists have presumed, that although the bile is secreted in a continuous manner, it only flows into the duodenum during chylification; at other times, the choledoch duct is contracted, so that the bile is compelled to reflow through the cystic duct into the gall-bladder; and it is only when the gall-bladder is filled, that it passes freely into the duodenum. Independently, however, of other objections to this view, vivisections have shown, that if the orifice of the choledoch duct be exposed, whatever may be the circumstances in which the animal is placed, the bile is seen issuing *guttatim* at the surface of the intestine. That the flow of bile from the gall-bladder, however, is dependent upon the presence of aliment in the intestines, is shown by the fact, that the reservoir is almost always found turgid in those who have died from starvation; the secretion formed at the ordinary slow rate having gradually accumulated for want of demand. This fact, it has been properly remarked, is important in juridical inquiries.

The biliary secretion, which proceeds immediately from the liver—*hepatic bile*—differs from that obtained from the gall-bladder,—*cystic bile.* The latter possesses greater bitterness; is thicker, of a deeper colour; and is that which has been usually analyzed. It is of a yellowish-green colour; viscid; and slightly bitter. It combines readily with water in all proportions; mixes freely with oil or fat; and foams, when stirred, like soapy water. It is, indeed, in common use in the same way as soap for cleansing articles of dress, and especially for taking out grease. Its chemical properties have been frequently examined; yet much is still needed, before we can consider the analysis satisfactory. Cystic bile has been generally supposed to have an alkaline reaction; but M. Bouisson, Dr. Kemp, and Von Gorup-Besanez,[1] and others who examined it, state, that when fresh and perfectly healthy, it is neutral. The last observer found it at first neutral; but

[1] Untersuchungen über Galle, S. 17, Erlangen, 1846.

in the early periods of its decomposition it is apt to become acid, and afterwards alkaline. The effects of bile, however, on test papers are difficult to appreciate, on account of the yellow stain it gives them. It has been examined by Boerhaave, Verheyen, Baglivi, Hartmann, Macbride, Ramsay, Gaubius, Cadet, Fourcroy, Maclurg, Thénard, Berzelius, Chevreul, Leuret and Lassaigne, Frommherz and Gugert, Schultz, Vogel, John, Treviranus, Tiedemann and Gmelin, Bouisson, Liebig, Kemp, Platner, Frerichs, Von Gorup-Besanez, Mulder, Bensch, Strecker, &c.,[1] &c. Thénard's[2] analysis of 1100 parts of human bile is as follows:—water, 1000; albumen, 42; resinous matter, 41; yellow matter, (*cholepyrrhin*, *biliphæin*), 2 to 10; free soda, 5 or 6; phosphate and sulphate of soda, chloride of calcium, phosphate of lime, and oxide of iron, 4 or 5. According to M. Chevallier, it contains also a quantity of picromel or *bilin*. Berzelius[3] called in question the correctness of M. Thénard's analysis, and gave the following:—water, 908·4; bilin, 80; albumen, 3·0; soda, 4·1; phosphate of lime, 0·1; common salt, 3·4; phosphate of soda, with some lime, 1·0. His analysis of ox-gall gave, water, 928·380; solid constituents, 71·620; bilin, 50·000; chloride of sodium, lactate of soda, and extractive matter soluble in alcohol, 4·334; cholesterin, ·001; mucus, 2·350. In a more recent essay[4] he gives the proportions in man as follows:—water, 90·44; bilin, 8·00; mucus of the gall-bladder, 0·30; alkali associated with bilin, 0·41; chloride of sodium; alkaline lactate, and extractive matters, 0·74; phosphates and sulphates of soda and lime, 0·11. The results of Dr. Davy's[5] analysis of healthy bile were as follows:—water, 86·0; resin of bile, 12·5; albumen, 1·5. The experiments of Gmelin, for which he is highly complimented by Berzelius,[6] although the latter considers, that some of the products may have been formed by the reaction of elements upon each other—yielded the following results:—an odorous material, like musk; cholesterin; oleic acid; margaric acid; cholic acid; resin of bile; taurin (g a l l e n a s p a r a g i n); bilin; colouring matter; osmazome; a substance which, when heated, had the odour of urine; another resembling bird-lime, gleadin; albumen (?); mucus of the gall-bladder; casein, or a similar substance; ptyalin, or a similar matter; bicarbonate of soda; carbonate of ammonia; acetate of soda; oleate, margarate, cholate, and phosphate of potassa and soda; chloride of sodium, and phosphate of lime. Cadet[7] considered bile as a soap with a base of soda, mixed with sugar of milk,—a view, which Raspail,[8] Demarçay,[9] Liebig and others think, harmonizes most with observed facts. Every other substance met with in the bile, M. Raspail looks upon as accessory. M. Demarçay regards it as a soda salt;

[1] Lehmann, Lehrbuch der Physiologischen Chemie, ii. 61, Leipzig, 1850; and Amer. edit. of Dr. Day's translation, i. 458, Philad., 1855.

[2] Mém. de la Société d'Arcueil, i. 38, Paris, 1807.

[3] Medico-Chirurgical Transactions, iii. 241.

[4] Art. Galle, Handwörterbüch der Physiologie, 3te Lieferung, s. 518, Braunschweig, 1842.

[5] Monro's Elements of Anatomy, i. 579.

[6] Henle, art. Galle, in Encyclop. Wörterb. u. s. w. B. xiii. S. 126, Berlin, 1835.

[7] Expériences sur la Bile des Hommes, &c., in Mém. de l'Académ. de Paris, 1767.

[8] Chimie Organique, p. 451, Paris, 1833.

[9] Annal. der Pharmac., xxvii., cited by Liebig, Animal Chemistry, Webster's edit., p. 305, Cambridge, Mass.

and regards the essential constituents to be an oily acid, which he terms *choleic*, and soda, which exists in a state of combination with it. Again, it has been analyzed by Muratori,[1] who assigns it the following constituents;—water, 832; peculiar fatty matter, 5; colouring matter, 11; cholesterin combined with soda, 4; picromel of Thénard, 94·86; osmazome (*estratto di carne*), 2·69; mucus, 37; soda, 5·14; phosphate of soda, 3·45; phosphate of lime, 3; and chloride of sodium, 1·86. Von Gorup-Besanez,[2] who found oxide of iron as a common constituent of the ashes of the bile, states, that copper can generally be detected in it in health; and constantly in biliary calculi.

One of the most recent analyses of human bile is given by Frerichs.[3] It was obtained from healthy men killed by severe accidents. The following is one analysis:—water, 86·00; solid constituents, 14·00; bilate of soda [choleate of soda?] 10·22; cholesterin, 0·16; margarin and olein, 0·32; mucus, 2·66; chloride of sodium, 0·25; tribasic phosphate of soda, 0·20; basic phosphate of lime, basic phosphate of magnesia, 0·18; sulphate of lime, 0·02; peroxide of iron, traces.

Fig. 173.

Crystals of Cholesterin, with Mucous Corpuscles and Blood-discs.

The proportion of solid matter in the bile is usually from 9 to 12 per cent., nearly the whole of which consists of cholesterin and bilin. Cholesterin is almost altogether composed of carbon and hydrogen. Bilin contains nitrogen. Its formula is $C^{76}H^{66}O^{22}N^{2}$ and a certain amount of sulphur.

One cause of the discrepancies in the analyses of bile is considered to be the facility with which it undergoes decomposition. Such has long been the opinion of distinguished chemists, as Berzelius and Mulder, and it is held by a more recent analyst, Strecker, who affirms that bile consists essentially of two soda salts, formed of soda and two resinous acids—one of them containing nitrogen and no sulphur; the other a large quantity of sulphur and no nitrogen. Bilin, in other words, is, according to him, a compound substance formed of cholate or glycocholate, and of sulpho-cholate, choleate or taurocholate of soda,—all the other products obtained from it being the results of its decomposition.[4]

[1] Bulletino Mediche di Bologna, p. 160, Agosto et Settembre, 1836.

[2] Op. cit., S. 41.

[3] Hannov. Annal. 1 and 2, 1845, cited in Simon's Animal Chemistry, Sydenham edition, ii. 519, London, 1846.

[4] For the analyses of Gunderlach and Strecker, Mulder, and Bensch, see British and Foreign Medico-Chirurgical Review, Jan., 1849, p. 259; also, Carpenter's Principles of Human Physiology, 4th Amer. edit., p. 620; and for those of J. Redtenbacher, Bensch and Strecker, the Report of Scherer in Canstatt and Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, S. 78, Erlang., 1849.

Messrs. Kirkes and Paget[1] think, that the analysis of Berzelius is the most nearly correct of the many that have been published; but that, after all, its physiology is perhaps more illustrated by its ultimate elementary composition, which shows, that, compared with the organic parts of the blood, it contains a large preponderance of carbon and hydrogen, and a deficiency of nitrogen.

The specific gravity of bile, at 6° centigrade, according to M. Thénard, is 1·026, and John, Schübler and Kapff accord with him. Frerichs found it to be, in one case, 1·040; in another, 1·032. Schultz found that of an ox, after feeding, at 15° to be 1·026; of a fasting animal, 1·030.

Hepatic and cystic bile do not appear to differ materially from each other, except in the greater concentration of the different elements in the latter. MM. Leuret and Lassaigne[2] found them to be alike in the dog. M. Orfila,[3] however, affirms, that human hepatic bile does not contain picromel.

When bile is placed in contact with concentrated nitric acid, it first of all assumes a deep green tint, which passes to blue on the addition of a fresh portion of the acid, and to red if we continue to add the acid,—qualities which enable it to be detected in the urine, and in the serum of the blood of the jaundiced.[4] Examined with the microscope, it is seen to contain a few, and but a few, globules of mucus, proceeding, according to M. Mandl,[5] from the muciparous glands of the gall-bladder; lamellæ of cylinder-epithelium swimming in an amorphous liquid, and small yellowish globules. At times, crystals of cholesterin are also observed in it.

It is impracticable to fix upon any average amount of bile secreted in the 24 hours. This must vary according to the amount of food, and the number of times it is taken, independently of other circumstances. According to Burdach,[6] from the experiments of De Graaf and Keill on dogs, Haller inferred, that 24 ounces are secreted by man in that time. It was not, however, from the experiments of De Graaf and Keill, that Haller drew such inference, but from those of Maurice Van Reverhorst.[7] Liebig estimates the daily discharge at from 17 to 24 ounces.[8] In the experiments of M. Blondlot,[9] twelve and a half drachms on an average were found to be discharged from a fistulous opening in the gall-bladder of a dog; and if the liver of man be supposed—with Haller—to secrete four or five times as much as that of the dog, we should have from six to eight ounces as the average quantity of bile discharged into the intestinal canal of man in the twenty-four hours. The observations of Bidder and Schmidt[10] carry it, however, much beyond this—to from three to four pounds in the twenty-four hours.

[1] Manual of Physiology, 2d Amer. edit., p. 194, Philad., 1853.
[2] Recherches, &c., sur la Digestion, Paris, 1825.
[3] Elém. de Chimie, Paris, 1817.
[4] The Author's Practice of Medicine, 3d edit., i. 669, Philad., 1848.
[5] Manuel d'Anatomie Générale, p. 501, Paris, 1843.
[6] Die Physiologie, u. s. w. v. 260, Leipzig, 1835.
[7] Haller, Elementa Physiologiæ, lib. xxiii., sect. 3, § 30, Bern., 1764.
[8] Animal Chemistry, edited by Gregory, Amer. edit., p. 62, Cambridge, 1842.
[9] Essai sur les Fonctions du Foie, p. 61, Paris, 1846.
[10] Die Verdauungssäfte, u. s. w., S. 287, Mitau und Leipzig, 1852.

The amount of bile contained in the gall-bladder varies. In more than one hundred cases the largest quantity was 111·65 *grammes* (oz. 3·6): the smallest 4·60 *grammes* (dr. 1·18). The average quantity, according to the observations of Von Gorup-Besanez[1] is from 20 to 30 *grammes* (dr. 5·14 to dr. 7·72).

The great uses of the bile have been detailed under the head of digestion. It has been conceived to be a necessary depuratory excretion, separating from the blood matters, that would be injurious if retained. This last idea is probable, and it has been ingeniously urged by MM. Tiedemann and Gmelin,[2] who regard the function of the liver to be supplementary to that of the lungs—in other words, to remove hydrocarbon from the system. The arguments, adduced in favour of their position, are highly specious and ingenious. The resin of the bile, they say, abounds most in herbivorous animals, whose food contains a great disproportion of carbon and hydrogen. The pulmonary and biliary apparatuses are in different tribes of animals, and even in differnt animals of the same species, in a state of antagonism to each other. The size of the liver and the quantity of bile are not in proportion to the amount of food and frequency of eating, but inversely proportionate to the size and perfection of the lungs. Thus, in warm-blooded animals, that have large lungs, and live always in the air, the liver, compared with the body, is proportionally less than in those that live partly in water. The liver is still larger in proportion in reptiles, which have lungs with large cells incapable of rapidly decarbonizing the blood,—in fishes, which decarbonize the blood tardily by the gills; and, above all, in molluscous animals, which effect the same change very slowly, either by gills, or by small imperfectly developed lungs. Again;—the quantity of venous blood, sent through the liver, increases as the pulmonary system becomes less perfect. In the mammalia, and birds, the vena porta is formed by the veins of the stomach, intestines, spleen, and pancreas; in the tortoise, it receives also the veins of the hind legs, pelvis, tail, and the vena azygos; in serpents, the right renal, and all the intercostal veins; in fishes, the renal veins, and those of the tail and genital organs. Moreover, during the hibernation of certain of the mammalia, when respiration is suspended, and no food taken, the secretion of bile goes on. Another argument is deduced from the physiology of the fœtus, in which the liver is proportionally larger than in the adult, and the bile secreted copiously, as appears from the great increase of the meconium during the latter months of utero-gestation.

Their last argument is drawn from pathological facts. In pneumonia and phthisis, the secretion of bile, according to their observations, is increased; in diseases of the heart, the liver is enlarged; and in morbus cæruleus the organ retains its fœtal proportion. In hot climates, too, where, in consequence of the greater rarefaction of the air, respiration is less perfectly effected than in colder, a vicarious decarbonization of the blood is established by an increased flow of bile. That the separation of bile from the blood is not, however, an indispensable function, notwithstanding the experiments of Schwann, to be mentioned pre-

[1] Op. cit., S. 28.
[2] Die Verdauung nach Versuchen, &c., traduit par Jourdan, Paris, 1827.

sently, is shown by Dr. Blundell,[1] who gives the cases of two children that lived for four months, apparently well fed and healthy, and, on opening their bodies, it was found, that the biliary ducts terminated in a cul-de-sac, and, consequently, not a drop of bile had been discharged into the intestines.

Admitting, then, that the bile is in part a depuratory secretion, it is probable, that the depuration is effected from the blood of the hepatic artery as well as from that of the portal system. The veins of the stomach and small intestines necessarily absorb much heterogeneous matter, which may be separated by the liver, along with other products which might be injurious if they passed into the mass of the blood. Still, although ultimately perhaps largely excrementitious, but a small portion of it is thrown out of the economy by the intestinal canal, the remainder being absorbed from the mucous membrane. This is shown by the fact, that whilst the weight of the fæces discharged in the twenty-four hours has been estimated at five or six ounces, that of the bile has been reckoned at between three or four pounds; and Bidder and Schmidt infer, that the proportion of the effete rejected matters in the intestinal canal is not more than one-eighth, and probably under one-fifteenth, of its solid portion.[2]

The views of Liebig[3] on this function, as well as on that of the urinary secretion, are ingenious; and, if not true, are at least plausible. Venous blood, before reaching the heart, passes through the liver; arterial blood through the kidney; and both these organs separate from the blood substances that are incapable of serving for the nutrition of the tissues. The compounds which contain the nitrogen of the transformed tissues are collected in the urinary bladder; and, not being inservient to any further use, are expelled from the body. Those, again, which contain the carbon, are collected in the gall-bladder, in the form of a compound of soda—bile—which is miscible with water in every proportion, and passing into the duodenum mixes with the chyme. All those parts of the bile, which, during the digestive process, do not lose their solubility, return, during that process, into the circulation in a state of extreme division. The soda of the bile, and the highly carbonized portions which are not precipitated by a weak acid, retain the capability of being taken up by the absorbents of the small and large intestines—a capability which has been directly proved by the administration of enemata containing bile,—the whole of the bile having disappeared along with the injected fluid. Liebig affirms, that the constituents of bile cannot be recognized in the fæces of carnivorous animals; whence he infers that the whole of the bile has been reabsorbed; and—he believes—in order that its hydro-carbon may pass off by the lungs. This can scarcely, however, apply to man; and Liebig admits, that in the herbivora a certain portion of the elements of the bile can be discovered in the fæces. Certainly, a marked difference is observable in them when the biliary ducts are obstructed. As to the precise change effected on the bile in order to fit it for being reabsorbed,

[1] Stokes, Theory and Practice of Medicine, American Medical Library edition, p. 104, Philad., 1837.

[2] T. K. Chambers, Digestion and its Derangements, p. 178, Lond., 1856.

[3] Animal Chemistry, Gregory's edit., p. 57, Cambridge, Mass., 1843.

Liebig leaves us wholly in the dark. His observations on this matter afford room for interesting reflection; but they can only at present be regarded in the light of suggestions. It would appear, however, from the analyses of different observers, that the fæces of both children and adults contain scarcely any evidences of bile, except in cases in which they are hurried through the canal so that time is not allowed for its absorption.[1] Moreover, the experiments of Schwann[2] seem to show, that it is not a mere excretory fluid, but must be inservient to important purposes in the economy. He removed a portion of the common choledoch duct, and established an external fistulous opening into the gall-bladder, so that the bile, when secreted, might be discharged externally, and not be permitted to enter the intestine. The general result was, that of eighteen dogs operated upon, ten died of the immediate effects of the operation; and of the remaining eight, two recovered, and six died. In the latter, death appeared to result altogether from the removal of the bile. After the third day, they lost weight daily, and had every sign of inanition—as emaciation, muscular debility, uncertain gait, falling off of the hair, &c. They lived from seven to sixty-four days after the operation, and the longer they survived, the more marked were the signs of inanition. Licking the bile, as it flowed from the opening, and swallowing it, had no influence on the results. In the two dogs that recovered, the importance of the bile was equally shown; for it was found, when they were killed, that the passage of the bile into the intestine had been restored, and the period of its restoration was distinctly shown by their weight—which had previously been regularly and progressively decreasing—becoming augmented, and continuing to augment until it amounted to what it was before the operation; and likewise by the fistulous opening into the gall-bladder healing, and the discharge of bile ceasing. These experiments do not, however, lead to any exact inference as to the mode in which the bile exerts its important agency.

It is proper, however, to add, that Schwann's experiments, when repeated with some modifications by M. Blondlot,[3] led to very different results. In the first of these, an external fistulous opening was made into the gall-bladder of a dog, and the ductus communis choledochus having been tied in two places, it was divided between the ligatures. At first the animal appeared distressed, but in a few hours it recovered. The bile continued to flow from the external opening, and was constantly licked off. On the fifteenth day, the wound had healed with the exception of the small aperture through which the bile flowed. The dog was then muzzled to prevent his licking it; after which the fæces became discoloured and hard. At this time he had become much emaciated although he had eaten heartily; but he now began to regain his flesh, and at the end of three months was perfetly well and active, and so continued. Another animal, which was experimented on in the same way, and presented the same phenomena, was killed at the end of forty days, when it was found that the ductus communis choledochus

[1] Pettenkofer, cited by Von Gorup-Besanez, Untersuchungen über Galle, S. 51, Erlangen, 1846.

[2] Müller's Archiv., Heft ii., 1844.

[3] Essai sur les Fonctions du Foie et de ses Annexes, Paris, 1846.

had become completely obliterated. He subsequently[1] experimented on a dog, which lived five years after a biliary fistula had been established, by which the bile was all discharged. Until near the end of its existence, it did not appear to fall off in its nutrition, had a good appetite, and bore young yearly. From these experiments, M. Blondlot inferred, that the bile plays no important part in the process of digestion, and that it is essentially and wholly an excrementitious fluid.

If the excretion of the bile be prevented from any cause, we know that derangement of health is induced; but it is probable, that its agency in the production of disease is much overrated; and that, as M. Broussais has suggested, the source of many of the affections termed *bilious* is in the mucous membrane lining the stomach and intestines; which, owing to the heterogeneous matters constantly brought into contact with it, must be peculiarly liable to be morbidly affected. When irritation exists there, we can understand how the secretion from the liver may be consecutively modified,—the excitement spreading directly along the biliary ducts to the secretory organ.

It has been shown by M. Bernard,[2] on the strength of experiments instituted by him, that a regular function of the liver is the formation of sugar—glycogeny. The fact of the conversion of amylaceous into saccharine matter by the contact of blood, saliva, &c., has been elsewhere referred to;[3] but from his researches, it would follow, that the liver alone has the power of producing sugar without starch, and that such production is connected with the integrity of the pneumogastric nerves. M. Bernard, after several experiments, discovered that if the floor of the fourth ventricle was pierced within a very circumscribed space, in less than half an hour, a very considerable quantity of sugar—diabetic sugar—was found in the blood and urine, without the regimen of the animal having undergone any change whatever. This fact attracted his attention to the condition of the floor of the fourth ventricle in diabetic patients, and in one case, on dissection, two dark spots were observed on the part which must be penetrated to produce the sugar. Increased saccharine formation was likewise caused by pricking or gently galvanizing the eighth pair in the neck, whilst it was suspended by dividing both pneumogastrics. As the sugar is formed in the liver, it is conveyed away by the veins proceeding from the organ, and has been detected by M. Bernard in the hepatic veins, vena cava superior, and right cavities of the heart; whilst in other parts of the body the blood contains none or very feeble traces of it, except after the digestion of amylaceous substances, when a notable quantity may be found in all the veins. As the saccharine matter, produced by the liver under the circumstances mentioned, is not met with in the pulmonary veins, MM. Magendie[4] and Bernard inferred that it must have undergone destruction in the lungs; and they think it not impossible, that from such destruction the carbonic

[1] Gazette Médicale, 1851, No. 26, p. 407.

[2] Archives Générales, Nov., 1848; see, also, Ranking's Half-Yearly Abstract of the Medical Sciences, ix. 215, Jan. to June, 1849.

[3] Page 132.

[4] Report of M. Magendie's Lectures at the College of France, in Union M´dicale, Nos. 72, 75 and 79, and in British and Foreign Medico-Chirurgical Review, p. 545, Oct., 1849.

acid of respiration may result, as has been presumed by many physiologists to be the case with every form of sugar. All sugars, however, do not appear to be affected in the same manner. If, according to Magendie, we inject into the blood a solution of cane sugar, mannite, or the sugar of milk, the whole of it will be found in the urine; but if we inject glucose or grape sugar, except in large quantity, none of it can be detected in that fluid. But if an animal be fed on the first mentioned varieties of sugar, they are not found in the urine; because, according to M. Magendie, digestion has transformed them into glucose, and this has become decomposed in the lungs. The following table is given by him to exhibit the quantity of the different kinds of sugar that must be injected into the jugular vein, in order that they may be detected in the urine. It shows—as he has remarked—that "the natural sugar of the economy is destroyed in the act of respiration with far greater facility than that proceeding from alimentary substances:—

Cane sugar,	0·05
Mannite,	0·05
Sugar of milk,	0·25
Glucose,	2·50
Sugar of the liver,	12·00

M. Bernard[1] found sugar in the livers of both the carnivora and herbivora; and when fasting as well as when digesting. In the carnivora, no sugar could be detected in the blood of the vena porta, whilst it was present in considerable quantity in that of the hepatic veins; whence he properly infers that the sugar is formed in the liver. The blood, moreover, which leaves the liver, whilst it contained more sugar than that which entered it, was found to have no more fibrin and much less albumen; hence his corollary that "the sugar appears to be formed in the liver at the expense of the albuminoid matters of the blood." A report made to the French Academy of Sciences on various and varied experiments by a committee of that body confirms most of the statements of M. Bernard. They did not find, however, that animals fed on flesh afforded the same amount of sugar as those fed on starch or sugar.[2]

As to the precise mode in which the sugar is produced in the liver we have no knowledge. It is probably by the agency of hepatic cells, from which it passes into the hepatic veins. The liver, consequently—to use the language of M. Bernard[3]—has an *external secretion*—that of the bile—which is discharged; and an *internal secretion*—that of sugar, which enters immediately into the blood of the general circulation. Sugar—to employ the language of Dr. C. Handfield Jones,[4] in his last communication on the liver—"seems to be the normal product of the cells,—bile of the ultimate biliary ducts."

The liver, consequently, not only secretes bile, but is a great assimilating organ; and that it is the seat of energetic nutritive action is shown by the experiments, hereafter referred to, by MM. Bernard and Walferdin, which exhibited a higher temperature of the blood where

[1] Leçons de Physiologie Expérimentale, &c., p. 477, Paris, 1855.
[2] Lancet, July 28, 1855. [3] Ibid., p. 100.
[4] Philosophical Transactions, vol. clxiii. pt. 1, p. 21, London, 1853.

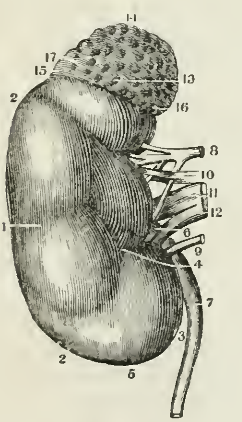
the supra-hepatic veins enter the vena cava ascendens than in any other part of the body.

6. *Secretion of the Kidneys.*

This is the most extensive secretion accomplished by any of the glandular structures of the body, and is essentially depuratory; its suppression giving rise to formidable evils. The apparatus consists of the *kidneys*, which secrete the fluid; the *ureters*, which convey the urine to the bladder; the *bladder* itself, which serves as a reservoir for the urine; and the *urethra*, which conveys the urine externally. These require a distinct consideration.

The *kidneys* are two glands situate in the abdomen; one on each side of the spine, in the posterior part of the lumbar region. They are without the cavity of the peritoneum, which covers them at the anterior part only; and are situate in the midst of a considerable mass of adipous areolar tissue. The right kidney is nearly an inch lower than the left, owing to the presence of the thick posterior margin of the right lobe of the liver. Occasionally, there is but one kidney; at other times, three have been met with. They have the form of the *haricot* or *kidney bean*, which has indeed, been called after them; and are situate vertically,—the fissure being turned inwards. If we compare them with the liver, their size is by no means in proportion to

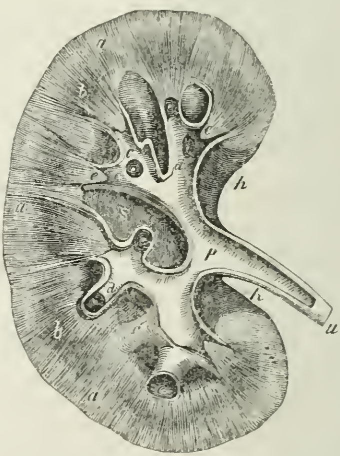
Fig. 174.



Right Kidney with its Renal Capsule.

1. Anterior face of kidney. 2. External or convex edge. 3. Its internal edge. 4. Hilum renale. 5. Inferior extremity of kidney. 6. Pelvis of ureter. 7. Ureter. 8, 9. Superior and inferior branches of emulgent artery. 10, 11, 12. Three branches of the emulgent vein. 13. Anterior face of renal capsule. 14. Its superior edge. 15. Its external edge. 16. Its internal extremity. 17. Fissure on the anterior face of the capsule.

Fig. 175.



Plan of a Longitudinal Section of the Kidney and Upper Part of the Ureter, through the Hilus, copied from an enlarged model.

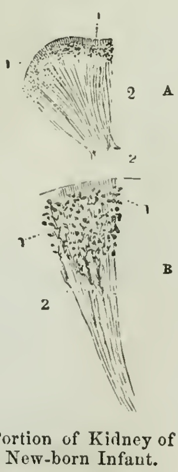
a, a, a. The cortical substance. *b, b.* Broad part of two of the pyramids of Malpighi. *e, e.* Section of the narrow part or apex of two of these pyramids, lying within the divisions of the ureter marked *c, c.* *d, d.* Summits of the pyramids, called papillæ, projecting into and surrounded by the divisions of the ureter. *c, c.* Divisions of the ureter, called the calices or infundibula, laid open. *c′.* A calix or infundibulum unopened. *p.* Enlarged upper end of ureter, named the pelvis of the kidney. *s.* Central cavity or sinus of the kidney.

the extensive secretion effected by them. Their united weight does not amount to more than six or eight ounces. Of 65 male kidneys, weighed by Dr. John Reid,[1] the average was found to be 5 oz. 7 dr. for the right kidney; 5 oz. 11½ dr. for the left. Of 28 female kidneys, the right weighed 4 oz. 13 dr.; the left, 5 oz. 2 dr. The left kidney generally weighs more than the right at all ages. The kidneys of the new-born child, although absolutely much lighter than those of the adult, are yet, according to M. Huschke,[2] in proportion to the whole body much heavier; inasmuch as their weight is to that of the whole body of the infant, as 1 to 82–100; in the adult as 1 to 225. They, therefore, do not grow uniformly with the body, although the secretion of urine becomes more energetic after birth.

The kidneys are hard, solid bodies, of a brown colour. The sanguiferous vessels, which convey and return the blood to them, as well as the excretory duct, communicate with them at the fissure.

The anatomical constituents of these organs are;—1. The *renal artery*, which arises from the abdominal aorta at a right angle, and, after a short course, enters the kidney, ramifying in its substance. 2. The *excretory ducts*, which arise from every part of the tissue, in which the ramifications of the renal artery terminate. They end in the *pelvis* of the kidney. (Fig. 175.) 3. The *renal veins*, which receive the superfluous blood, after the urine has been separated from it, and terminate in the *renal* or *emulgent vein*, which issues at the fissure, and opens into the abdominal vena cava. 4. Lymphatic vessels, arranged in two planes—a superficial and a deep-seated, which terminate in the lumbar glands. 5. *Nerves*, which proceed from the semilunar ganglion, solar plexus, &c., and surround the renal artery as with a network, following it in all its ramifications. 6. Areolar membrane, which, as in every other organ, binds the parts together. These anatomical elements, by their union, constitute the organ as we find it.

Fig. 176.



Portion of Kidney of New-born Infant.

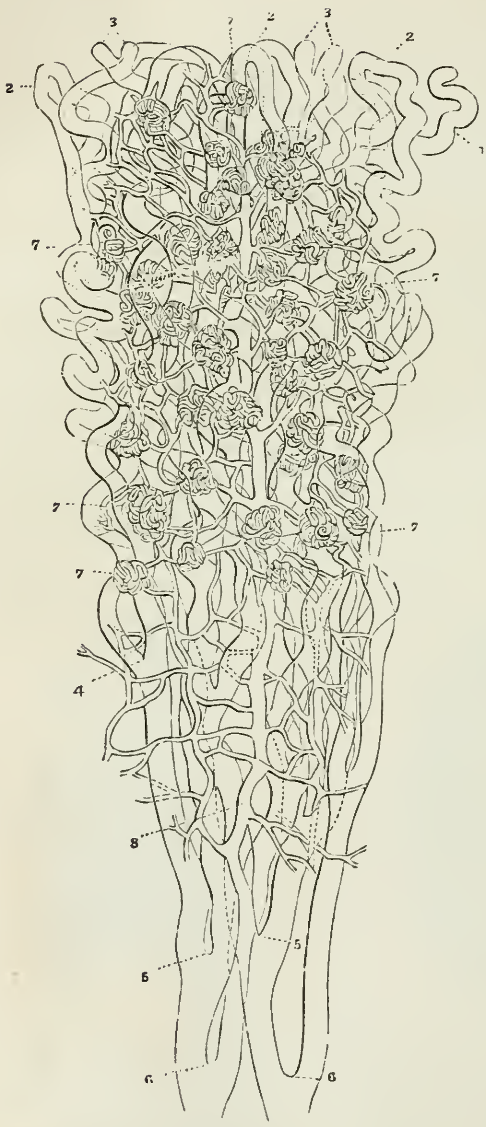
A. Natural size. B. A small portion of A magnified. 1, 1. Corpora Malpighiana. 2. Tubuli uriniferi.

When the kidney is divided longitudinally, it is seen to consist of two substances, which differ in their situation, colour, consistence, and texture. One of these, and the more external, is called the *cortical, glandular* or *vascular substance*. It forms the whole circumference of the kidney; is about two lines in thickness; of less consistence than the other; of a pale red colour; and receives almost entirely the ramifications of the renal artery. The other and innermost is the *tubular, medullary, uriniferous, conoidal* or *radiated substance*. It is more dense than the other; less red; and seems to be formed of numerous minute tubes, which unite in conical bundles of unequal size —*pyramids of Malpighi*—the base of which is turned towards the cortical portion,—the apices forming the *papillæ* or *mammillary processes*, and facing the pelvis of the kidney. The papillæ vary in number from five to eighteen; are of a florid colour; and upon their points or apices are terminations of uriniferous tubes large

[1] Lond. and Edinb. Monthly Journal of Med. Science, April, 1843, p. 323.
[2] Encyclop. Anatom., traduit par Jourdan, v. 321, Paris, 1845.

enough to be distinguished by the naked eye. Around the root of each papilla, a membranous tube arises called *calix* or *infundibulum;* this receives the urine from the papilla, and conveys it into the *pelvis* of the kidney, which may be regarded as the commencement of the ureter.

Fig. 177.



Small Portion of Kidney magnified 60 diameters.

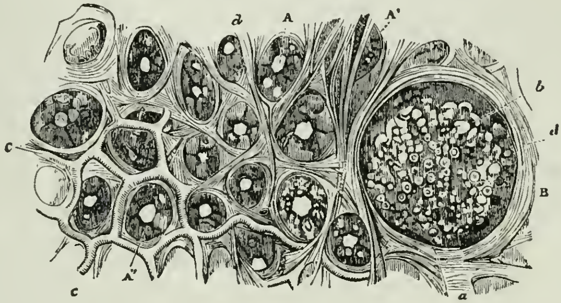
1. Cæcal extremity of a tubulus. 2, 2. Loops of tubuli. 3, 3. Bifurcated tubuli. 4, 5, 6. Tubuli converging towards the papillæ. 7, 7, 7. Corpora Malpighiana. 8. Arterial trunk.

The cortical part of the kidney is the most vascular; and the plexus formed by the tubuli uriniferi appears to come there in closest relation with that formed by the renal capillaries. The *corpora Malpighiana* or Malpighian bodies appear as points in the cortical substance. They are scattered through the plexus formed by the bloodvessels and uriniferous tubes. Each one, when examined by a high magnifying power, is found to consist of a convoluted mass of minute bloodvessels. In them—it was at one time supposed—the uriniferous tubes originate; but the examinations of Müller and Huschke have seemed to show, that they are only capable of injection from the arteries or veins. They are found in the kidneys of most, if not all, of the vertebrata. In the cortical substance, according to Wagner,[1] the tubuli can be traced, although with

[1] Elements of Physiology, by R. Willis, § 193, Lond., 1842.

difficulty, winding among the vascular plexuses or skeins, mostly looped towards the margin of the organ, and running into one another, or having blind or cæcal extremities; more rarely enlarged and club-shaped, and occasionally cleft. The entire cortical substance, according to Wagner, consists of convolutions of the uriniferous tubes, which present a nearly uniform diameter, on an average, from about the 60th to the 50th of a line. Professor Goodsir,[1] however, without denying

Fig. 178.



Section of the Cortical Substance of the Human Kidney.

A, A. Tubuli uriniferi divided transversely, showing the spheroidal epithelium in their interior. B. Malpighian capsule. *a*. Its afferent branch of the renal artery. *b*. Its glomerulus of capillaries. *c*, *c*. Secreting plexus, formed by its efferent vessels. *d*, *d*. Fibrous stroma.

the existence of occasional blind extremities of the tubuli uriniferi—the result probably, he thinks, of arrested developement—states, that he has never seen the ducts terminate in this way. He has described a fibro-areolar framework, which, pervading every part of the gland, and particularly its cortical portion, performs the same office in the kidney as the capsule of Glisson does in the liver,—being a basis of support to the delicate structure of the gland, conducting the bloodvessels through the organ, and constituting small chambers in the cortical portion, in each of which a single ultimate coil or loop of the uriniferous ducts is lodged. Mr. Goodsir believes, that the urine is formed at first within the epithelium cells of the ducts, and that these burst, dissolve, and throw out their contents, and are succeeded by others, which perform the same functions. The urine of man has not been detected by Mr. Goodsir within the cells, that line the ducts, but he has submitted to the Royal Society

Fig. 179.

Tubuli Uriniferi.

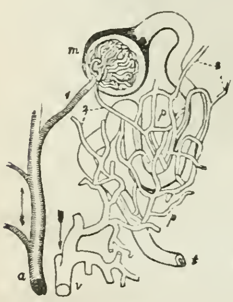
A. Portion of a secreting canal from the cortical substance of the kidney. B. The epithelium or gland-cells, more highly magnified (700 times). C. Portion of a canal from the medullary substance of the kidney. At one part the basement membrane has no epithelium lining it.

[1] Lond. and Edinb. Monthly Journ. of Med. Science, May, 1842.

of Edinburgh a memoir, already referred to, in which he has endeavoured to show, that urine, bile, and milk, as well as the other more important secretions in the lower animals, are formed within the nucleated cells of the ducts themselves; and he is of opinion, that the urine of man is poured at first into the cavities of the nucleated cells of the human kidney.

Mr. Bowman[1] describes the kidney as furnished with a true *portal system*, and is of opinion that the urine, like the bile, is secreted—in part at least—from blood, traversing a second set of capillaries. According to him, each of the exceedingly tortuous and convoluted urinary conduits terminates, at its final extremity, by a contracted neck, which leads into a little chamber or cyst,—*capsule of Malpighi*—in which is contained the true *glandule*, *corpuscle* or *glomerule* of Malpighi. This consists of a tuft or coil of capillary bloodvessels, totally naked, which originates in one of the ultimate branches of the renal artery, and terminates in an efferent vessel. Several of these latter form, by their anastomosing ramifications, the plexus that surrounds each urinary conduit and tubule, the urinary conduits being lined by thick epithelium, and their necks furnished with vibratile cilia. All the blood of the renal artery, according to Mr. Bowman,—with the exception of a small quantity distributed to the capsule, surrounding fat, and the coats of the larger vessels,—enters the capillary tufts of the corpora Malpighiana; thence passes into the capillary plexus surrounding the uriniferous tubes, and finally leaves the organ through the branches of the renal vein. According to this view, there are in the kidney two perfectly distinct systems of capillary vessels; the *first*, that inserted into the dilated extremities of the uriniferous tubes, and in immediate connexion with the arteries—the Malpighian bodies;—the *second*, that enveloping the convolutions of the tubes, and communicating directly with the veins. The efferent vessels of the Malpighian bodies, that carry the blood between these two systems, are termed by Mr. Bowman the *portal system of the kidney*. The views of Mr. Bowman have been embraced by many histologists,[2] whilst every one of them has been strenuously denied by others. In regard to the precise arrangement of the Malpighian bodies, histologists are by no means in accordance. Gerlach for example, found, that instead of the flask-like dilatation being placed, as maintained by Mr. Bow-

Fig. 180.



Plan of the Renal Circulation.

a. A branch of the renal artery giving off several Malpighian twigs. 1. An afferent twig to the capillary tuft contained in the Malpighian body, *m*; from the Malpighian body the uriniferous tube is seen taking its tortuous course to *t*. 2, 2. Efferent veins; that which proceeds from the Malpighian body is seen to be smaller than the corresponding artery. *p*, *p*. The capillary venous plexus, ramifying upon the uriniferous tube. This plexus receives its blood from the efferent veins, 2, 2, and transmits it to the branch of the renal vein, *v*.

[1] Proceedings of the Royal Society, No. lii., Feb. 3, 1842; and Philos. Transactions, Pt. 1, p. 57, Lond., 1842.

[2] See on the whole subject Dr. Geo. Johnson, in the article Ren, Cyclopædia of Anatomy and Physiology, Pt. xxxii. p. 244, Lond., August, 1848; Gerlach, Handbuch der Gewebelehre, S. 301, Mainz, 1849; and A. H. Hassall, The Microscopic Anatomy of the Human Body, Pt. xiii. p. 427, Lond., 1848.

man, at the extremity of a uriniferous tube, it may be, and is formed by off-sets from the sides of the tube; so that the capsules may be either terminal or lateral.[1]

In the quadruped, each kidney is made up of numerous lobes, which are more or less intimately united according to the species. In birds, the kidney consists of a double row of distinct, but connected, glandular bodies, placed on both sides the lumbar vertebræ.

The *ureter* is a membranous duct, which extends from the kidney to the bladder. It is about the size of a goosequill; descends through the lumbar region; dips into the pelvis by crossing in front of the primitive iliac vessels and the internal iliac; crosses the vas deferens at the back of the bladder; and, penetrating that viscus obliquely, terminates by an orifice ten or twelve lines behind that of the neck of the bladder. At first, it penetrates two of the coats only of that viscus; running for the space of an inch between the mucous and muscular, and then entering the cavity. The ureters have three coats. The outermost is a dense fibrous membrane; the second a smooth muscular layer, which is very distinct, with external longitudinal, and internal transverse fibres, to which, towards the bladder, internal longitudinal fibres are added. In the pelvis of the kidney the two muscular layers are as thick as in the ureter; but in the calices they become thinner and thinner, and cease where the latter are inserted into the papillæ.[2] The innermost coat is a thin mucous layer, which is continuous at its lower extremity with the inner coat of the bladder; and, at the upper end, supposed by some to be reflected over the papillæ, and even to pass for some distance into the tubuli uriniferi.

The *bladder* is a musculo-membranous sac, situate in the pelvis; anterior to the rectum, and behind the pubes. Its superior end is called *upper fundus;* and the lower end, *inferior fundus* or *bas fond;* the *body* being between the two. The part where it joins the urethra is the *neck.* The shape and situation of the organ are influenced by age and sex. In very young infants, it is cylindroid, and rises almost wholly into the abdomen. In the adult female, who has borne many children, it is nearly spherical; has its greatest diameter transverse, and is more capacious than in the male. Like the other hollow viscera, the bladder consists of several coats. 1. The *peritoneal*, which covers only the fundus and back part. Towards the lower portion the organ is invested by areolar membrane, which takes the place of the peritoneal coat of the fundus. This tissue is very loose, and permits the distension and contraction of the bladder. 2. The *muscular coat* is very strong; so much so, that it has been classed amongst the distinct muscles, under the name *detrusor urinæ.* The fibres are pale, unstriped, and pass in various directions. Towards the lower part of the bladder, they are particularly strong; arranged in fasciculi, and form a kind of network of muscles enclosing the bladder. In cases of stricture of the urethra, where much effort is necessary to expel the urine, these fasciculi acquire

[1] Gerlach, op. cit., and in Müller's Archiv. für Anatomie, S. 378, 1845; and Ibid., S. 102, 1848.

[2] Kölliker, Mikroskopische Anatomie, 2ter Band. S. 365, Leipzig, 1854; and Amer. edit. of Sydenham Society's edit. of his Manual of Human Histology, by Dr. Da Costa, p. 607, Philad., 1854.

considerable thickness and strength. 3. The *mucous* or *villous coat* is the lining membrane, which is continuous with that of the ureters and urethra, and is generally rugous in consequence of its being more extensive than the muscular coat without. It is furnished with numerous follicles, which secrete a fluid to lubricate it. Towards the neck of the organ, it is thin and white, although reddish in the rest of its extent. A fourth coat, called the *cellular* or *areolar* has been reckoned by most anatomists, but it is nothing more than areolar tissue uniting the mucous and muscular coats. The part of the internal surface of the bladder, situate immediately behind and below its neck, and occupying the space between it and the orifices of the ureters, is called *vesical triangle*, *trigonus Lieutaudi* or *trigone vésical.* The anterior angle of the triangle looks into the orifice of the urethra, and is generally so prominent, that it has obtained the name *uvula vesicæ.* It is merely a projection of the mucous membrane, dependent upon the subjacent third lobe of the prostate gland, which, in old people, is frequently enlarged, and occasions difficulty in passing the catheter. The neck of the bladder penetrates the prostate; but, at its commencement, it is surrounded by loose areolar tissue, containing a very large and abundant plexus of veins. The internal layer of muscular fibres is here transverse; and they cross and intermix with each other in different directions, forming a close, compact tissue, which has the effect of a particular apparatus for retaining the urine, and has been called the *sphincter.* Anatomists have not usually esteemed this structure to be distinct from the muscular coat at large; but Sir Charles Bell[1] asserts, that if we begin the dissection by taking off the inner membrane of the bladder from around the orifice of the urethra, a set of fibres will be discovered on the lower half of the orifice, which, being carefully dissected, will be found to run in a semicircular form around the urethra. These fibres make a band of about half an inch in breadth, particularly strong on the lower part of the opening; and having ascended a little above the orifice on each side, they dispose of a portion of their fibres in the substance of the bladder. A smaller and somewhat weaker set of fibres will be seen to complete their course, surrounding the orifice on the upper part. The arteries of the bladder proceed from various sources, but chiefly from the umbilical and common pudic. The veins return the blood into the internal iliacs. They form a plexus of considerable size upon each side of the bladder, particularly about its neck. The lymphatics accompany the principal veins of the bladder, and, at the under part and sides, pass into the iliac glands. The nerves are from the great sympathetic and sacral.

The *urethra* is the excretory duct of the bladder. It extends, in the male, from the neck of the bladder to the extremity of the glans; and is from seven to ten inches in length. In the female it is much shorter. The male urethra, in the state of flaccidity of the penis, has several curvatures; but is straight or nearly so, if the penis be drawn forwards and upwards, and the rectum be empty. The first portion of this canal, which traverses the prostate gland, is called the *prostatic portion.* Into it open,—on each side of a caruncle, called *verumontanum*, *caput galli-*

[1] Anatomy and Physiol., 5th Amer. edit. by Dr. Godman, ii. 375, New York, 1829.

naginis or *crista urethralis*,—the two ejaculatory ducts, those of the prostate, and a little lower, the orifice of Cowper's glands. Between the prostate and the bulb is the *membranous part* of the urethra, which is eight or ten lines long. The remainder of the canal is called *corpus spongiosum* or *spongy portion*, because surrounded by an erectile spongy tissue. It is situate beneath the corpora cavernosa, and passes forward to terminate in the *glans*, the structure of which will be considered under Generation. At the commencement of this portion of the urethra is the *bulb*, the structure of which resembles that of the corpora cavernosa of the penis—to be described hereafter. The dimensions of the canal are various. At the neck of the bladder it is considerable; behind the caput gallinaginis it contracts, and immediately enlarges in the forepart of the prostate. The membranous portion is narrower; and in the bulb the channel enlarges. In the body of the penis, it diminishes successively, till near the glans, when it is so much increased in size as to have acquired the name *fossa navicularis*. At the apex of the glans it terminates by a short vertical slit. Mr. Shaw[1] has described a set of vessels, immediately on the outside of the internal membrane of the urethra, which, when empty, are very similar in appearance to muscular fibres. These vessels, he remarks, form an internal spongy body, which passes down to the membranous part of the urethra, and forms even a small bulb there. Dr. Horner,[2] however, says, that this appeared to him to be rather the areolar membrane connecting the canal of the urethra with the corpus spongiosum. The whole of the urethra is lined by a very vascular and sensible mucous membrane, which is continuous with the inner coat of the bladder. It has, apparently, a certain degree of contractility; and therefore, by some anatomists, is conceived to possess muscular fibres. Sir Everard Home, from the results of his microscopical observations, is disposed to be of this opinion. This is, however, so contrary to analogy, that it is probable the fibres may be seated in the tissue surrounding it. The membrane contains numerous follicles, and several lacunæ, one or two of which, near the extremity of the penis, are so large as occasionally to obstruct the catheter, and convey the impression that a stricture exists.

The prostate and glands of Cowper, being more concerned in generation, will be described hereafter.

There are certain muscles of the perineum, that are engaged in the expulsion of the urine from the urethra; and some of them in defecation, and the evacuation of sperm likewise;—as the *acceleratores urinæ* or *bulbo-urethrales*, which propel the urine or semen forward;[3] the *transversus perinei* or *ischio-perinealis*, which dilates the bulb for the reception of the urine or sperm; the *sphincter ani*, which draws down the bulb, and aids in their ejection; and the *levator ani*, which surrounds the extremity of the rectum, the neck of the bladder, the membranous portion of the urethra, the prostate gland, and a part of the vesiculæ seminales, and assists in the evacuation of the bladder, vesiculæ seminales, and prostate. A part of the levator, which arises

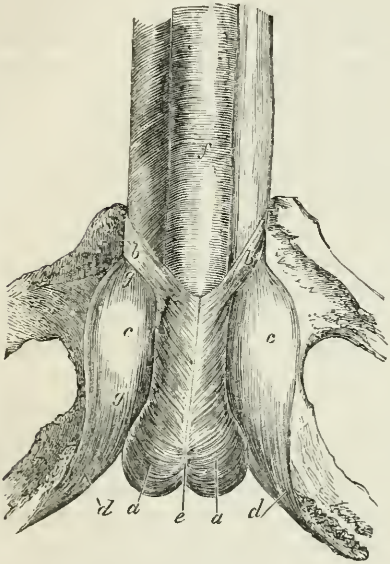
[1] Manual of Anatomy, ii. 118, Lond., 1822.

[2] Lessons in Practical Anatomy, 3d edit., p. 272, Philad., 1836.

[3] For Dr. Horner's views on the origin of the acceleratores urinæ, see his Special Anatomy and Histology, 8th edit., Philad., 1851.

from the pubis and assists in inclosing the prostate, is called by Sömmering *compressor prostatæ.* Between the membranous part of the urethra, and that portion of the levator ani which arises from the inner side of the symphysis pubis, a reddish, areolar, and very vascular substance exists, which closely surrounds the canal, has been described by Mr. Wilson[2] under the name *compressor urethræ*, and is termed, by some of the French anatomists, *muscle de Wilson.* By many, however, it is considered to be a part of the levator ani. M. Amussat asserts, that the membranous part of the urethra is formed externally of muscular fibres, which are susceptible of energetic contraction; and M. Magendie[3] confirms his assertion.

Fig. 181.



Part of the Ossa Pubis and Ischia, with the Root of the Penis attached.[1]

a, a. Accelerator urinæ muscle, embracing the bulb of the urethra, which is slightly notched in the middle line, *e*, behind. *b, b.* Anterior slips of the accelerator muscle, which pass round to the dorsum of the penis. *c, c.* Crura of the penis. *d, d.* Erectores penis muscles lying on the crura. *f.* The corpus spongiosum urethræ. *g*, to *g.* Enlargement of the crus, named the bulb of the corpus cavernosum.

With regard to the *urinary organs of the female:*—the kidneys and ureters have the same situation and structure as those of the male. The bladder, also, holds the same place behind the pubis; but rises higher when distended. It is proportionally larger than that of the male, and is broader from side to side, thus permitting the greater retention to which females are often necessitated. The urethra is much shorter, being only about an inch and a half, or two inches long; and it is straighter than in the male, having only a slight curve downwards between its extremities, and passing almost horizontally under the symphysis pubis. It has no prostate gland, but is furnished, as in the male, with follicles and lacunæ, which provide a mucus to lubricate it.

In birds in general, and in many reptiles and fishes, the urine, prior to expulsion, is mixed with the excrement in the cloaca. Nothing analogous to the urinary organs has been detected in the lowest classes of animals, although in the dung of the caterpillars of certain insects, traces of urea have been met with.

The urine is formed from the blood in the kidneys; and it has, until recently, been the universal belief, that it is secreted from arterial blood; Mr. Bowman, however, in accordance with views on the

[1] Kobelt, De l'Appareil du Sens Génital des deux Sexes, traduit de l'Allemand, par H. Kaula, D. M., Strasbourg, 1851.

[2] Lectures on the Structure and Physiology of the Urinary and Genital Organs, Lond., 1821.

[3] Précis, &c., ii. 472.

minute anatomy of the kidney already given, has attempted to show, that it is separated from venous blood. His main conclusions are as follows:—*First.* The epithelium lining the tubes is the proper organ that secretes the characteristic products of urine from the blood; and it does this by first assimilating them into its own substance, and afterwards pouring them upon its free surface. *Secondly.* These proper urinous products require for their solution a large quantity of water. *Thirdly.* This water is furnished by the Malpighian tufts of capillaries, placed at the extremity of the uriniferous tubes; and *Fourthly.* A farther use of the Malpighian bodies seems to be that of sharing in regulating the amount of water in the body. He thus makes a striking analogy between the liver and the kidney both in structure and function; and expresses his belief,—*first*, that diuretic medicines act specially on the Malpighian bodies, and that many substances, particularly salts, which, when taken into the system, have a tendency to pass off by the kidneys with rapidity, in reality escape through the Malpighian bodies: *secondly*, that certain morbid products occasionally found in the urine, such as sugar, albumen, and the red particles of the blood, in all probability, pass off through this bare system of capillaries. The discovery, however, by Gerlach,[1] and others, that the proper Malpighian capsule is invariably lined by innumerable granular cells, naturally suggested, that the Malpighian body is destined for some action of elaboration, and that it is as much concerned in the proper urinary secretion as the uriniferous tubes; and on these grounds Mr. Hassall expresses the belief, that urine is formed in every part of the tubular and Malpighian surface of the kidney; and he thus dissents from the opinion of Mr. Bowman, that the Malpighian body is an apparatus destined for the simple separation of the watery parts of the urine; whilst he agrees with him, that the greater portion of the more watery parts proceed from the Malpighian bodies;—which is probable. It is not so easy to accord with him, that the last action is not "effected by an act of simple separation but by one of secretion." A simple physical act of endosmose—it need scarcely be said—is alone needed in the case of a tenuous fluid; and cell agency is only required where an action of elaboration has to be exerted.

According to M. Raspail,[2] the urine is a kind of *caput mortuum*, ejected into the urinary bladder by the kidneys. They separate carbon and nitrogen in the form of cyanogen, which unites with oxygen to produce cyanic acid; and this combines with ammonia—itself a compound of nitrogen and hydrogen—to form urea, which is the characteristic element of the urinary secretion. They separate also, and excrete superfluous fluid from the body. The proofs of such separation are easy and satisfactory; but with regard to the mode in which the operation is effected, we are in the same darkness that hangs over glandular secretions in general. The transformation doubtless occurs mainly in the cortical part of the organ, and essentially in the same manner as other secretions are formed from the blood;—the action of

[1] Op. cit.

[2] Chimie Organique, p. 505, Paris, 1833.

elaboration taking place through the agency of cells, which burst and discharge the proper urinary matter into the uriniferous tubes.

The urinary secretion takes place continuously. If a catheter be left in the bladder, the urine drops constantly; and in cases of *exstrophia* of that organ—a faulty conformation, in which a red mucous surface, formed by the inner coat of the bladder, is seen in the hypogastric region on which two prominences are visible, corresponding to the openings of the ureters, the urine is observed to be constantly oozing from the openings.[1] A case of the kind the author has had repeated opportunities of exhibiting to his class in the Jefferson Medical College.

After the secretion has been effected in the cortical substance, it flows through the tubular, and issues *guttatim* through the apices of the papillæ into the pelvis of the kidney, whence it proceeds along the ureter to the bladder. If the uriniferous cones be slightly compressed, urine issues in greater quantity; but, instead of being limpid, as when it flows naturally, it is thick and troubled. Hence a conclusion has been drawn, that it is really filtered through the hollow fibres of the medullary or tubular portion. If this were the case, what must become of the separated thick portion? Ought not the tubes to become clogged up with it? And is it not more probable, that compression, in this case, forces out with the urine some of the blood that is concerned in the nutrition of the organ? The fresh secretion constantly taking place in the kidney causes the urine to flow along the tubuli uriniferi to the pelvis of the organ, whence, in the erect attitude, it proceeds along the ureter, by virtue of its gravity: the fluid, too, continually secreted from the kidney, pushes on that before it: moreover, it is now proved, that a contractile action is exerted by the ureters themselves; although, as in the case of the excretory ducts in general, such a power had been denied them. These, with the cilia of the lining membrane,[2] are the chief causes of the progression of the urine into the bladder, which is aided by the pressure of the abdominal contents and muscles; and, it is supposed, by the pulsation of the renal and iliac arteries; but the agency of these must be trivial.

The orifices of the ureters form the posterior angles of the *trigone vésical*, and are contracted somewhat below the size of the ducts themselves. They are said by Sir Charles Bell[3] to be furnished with a small fasciculus of muscular fibres, which runs backwards from the orifice of the urethra, immediately behind the lateral margins of the triangle; and, when it contracts, stretches the orifice of the ureter so as to permit the urine to enter the bladder with facility. As the urine passes in, it gradually distends the organ until the quantity has attained a certain amount. It cannot reflow by the ureters, on account of the smallness of their orifices and their obliquity; and as the bladder becomes filled,—owing to the duct passing for some distance be-

[1] A case of this kind is detailed by the author, in Amer. Med. Intelligencer, i. 137; and another by Dr. Pancoast, ibid., p. 147, Philad., 1838.

[2] On the Ciliary Motion of the Tubes, see Dr. George Johnson, art. Ren, supra cit., p. 253.

[3] Anatomy and Physiology, 5th American edition, by Godman, ii. 381, New York, 1827.

tween the muscular and mucous coats,—the sides are pressed against each other, so that the cavity is obliterated. As, however, the ureters have a tendency to lose this obliquity of insertion, in proportion as the bladder is emptied, the two bands of muscular fibres, which run from the back of the prostate gland to the orifices of the ureters, not only assist in emptying the bladder, but, at the same time, pull down the orifices of the ureters, and thus tend to preserve the obliquity. Moreover, when we are in the erect attitude, the urine would have to enter the ureters against gravity. These obstacles are so effective, that if an injection be thrown forcibly and copiously through the urethra into the bladder, it does not enter the ureters. On the other hand, equally powerful impediments exist to its being discharged through the urethra. The inferior fundus of the bladder is situate lower than the neck; and the sphincter presents a degree of resistance, which requires the bladder to contract forcibly on its contents, aided by the abdominal muscles to overcome it. Magendie[1] considers the contraction of the levatores ani to be the most efficient cause of the retention of the urine; the fibres which pass around the urethra pressing its sides against each other, and thus closing it. In a case of exstrophy of the bladder, Mr. Erichsen[2] had an opportunity of marking several interesting phenomena connected with the excretion of urine. The orifice of each ureter in the bladder appeared, when closed, as a small irregularly oval depression, about a line in diameter, situate on a conical papilla of the mucous membrane. A probe might be passed up the ureters for several inches without any sensible inconvenience being sustained. In regard to the phenomena attending the passage of the urine from the ureters into the bladder, it appeared, that in the first place a drop collected within the papillary termination of the ureter, which became somewhat distended; the orifice of the canal then opened to an extent of from two to three lines in diameter, and, as soon as it had allowed the drop of urine to pass, it contracted with a sphincter-like action. The distension of the lower end of the ureter, before the drop of urine escaped, was very distinct; and the relaxation of the orifice of the canal had the appearance of being occasioned by the accumulation of the drop of fluid that collected above it. The closure of the vesical termination of the ureter, after the escape of the drop of urine, was accompanied by a slight retraction of the papillary bulging of the mucous membrane on which it terminated, and the whole process resembled an ordinary sphincter action. The two ureters did not open at the same time, but with an irregularly alternating action. During the periods of fasting, they opened on an average about three times in a minute; consequently, the quantity of urine discharged from both might be estimated at about three large drops in the same space of time; but although this might be taken as the average rate of discharge, the action of the ureters was by no means regular, inasmuch as two or three drops would sometimes flow in rapid succession, whilst, at other times, a comparatively long interval would elapse between the escape of any two. When the patient lay upon his back, the discharge was slow and gentle, being

[1] Précis, &c., edit. cit., ii. 473.

[2] London Medical Gazette, 1845.

unattended with the distinct opening and shutting of the end of the tube noticed when in the upright position. During a deep inspiration, as in yawning or coughing, or whilst straining at stool, the flow of urine was suddenly increased, and the fluid escaped in a small stream, or in several large drops in rapid succession. The urine itself was invariably acid, and often highly so, whilst the mucous membrane of the bladder possessed a highly alkaline reaction. It was covered by a viscid glairy mucus, and was extremely sensitive to the touch.

Urine accumulates in the bladder until the desire arises to expel it: the number of times that a person in health and in the middle period of life discharges it in the twenty-four hours, varies: some evacuate the bladder but twice, others may be compelled to do so as many as twelve or fourteen times. Nine times, according to Dr. Thomas Thomson,[1] is a common number. The quantity discharged at a time varies. The greatest observed by Dr. Thomson was 25½ cubic inches or somewhat less than a pint; the most common from seven to nine cubic inches. During its stay in the bladder, it is believed to be deprived of some of its more aqueous portions by absorption, and to become of greater specific gravity, and more coloured: it is here that depositions are apt to take place, which constitute *calculi;* although they are met with in the kidneys and ureters also.

As in every excretion, a sensation first arises, in consequence of which the muscles required for the ejection of the secreted matter are called into action. This sensation occurs whenever the urine has accumulated to the necessary extent, or when it possesses irritating qualities, owing to extraneous substances being contained in, or deposited from, it; or if the bladder be unusually irritable from any morbid cause, the sensation may be repeatedly—nay, almost incessantly—experienced. The remarks that have been made on the sensations accompanying the other excretions are equally applicable here. The impression takes place in the bladder; whence it is conveyed to the brain, which accomplishes the sensation; and, consecutively, the muscles, concerned in the excretion, are called into action by volition. Physiologists have differed regarding the power of volition over the bladder. Some have affirmed, that it is as much under cerebral control as the muscles of locomotion; and they have urged, in support of this view, that the bladder receives spinal nerves, which are voluntary; that it is paralysed in affections of the spinal marrow, like the muscles of the limbs; and that a sensation, which seems destined to arouse the will, is always the precursor of its action. Others again have denied, that the muscular fibres are contractile under the will; and they adduce the case of other reservoirs,—the stomach and rectum, for example,—whose influence in excretion we have seen to be involuntary; as well as the fact that we feel the contraction of the bladder no more than we do that of the stomach or intestines; and they affirm, that the action of the bladder itself has been confounded with that of the accessory muscles, which are manifestly under the influence of the will, and are important agents in the expulsion of fluid from the bladder. The views last expressed appear to be most accurate, and the catenation of phenomena seems to be as

[1] British Annals of Medicine, p. 6, Jan., 1837.

follows:—the sensation to expel the urine arises; the abdominal muscles are thrown into contraction by volition; the viscera are thus pressed down upon the pelvis; the muscular coat of the bladder is, at the same time, stimulated by reflex action to contraction; the levatores ani and the sphincter fibres are relaxed, so that the resistance of the neck of the organ is diminished, and the urine is forced out through the whole extent of the urethra, being aided in its course, especially towards the termination, by the contractile action of the urethra itself, as well as by the levatores ani and acceleratores urinæ muscles. These expel the last drops by giving a slight succussion to the organ, and directing it upwards and forwards; an effect which is aided by shaking it to remove the drops that may exist in the part of the canal near its extremity. The gradually diminishing jet, which we notice as the bladder is becoming empty, indicates the contraction of the muscular coat of the organ; whilst the kind of intermittent jet, coincident with voluntary muscular exertion, indicates the contraction of the urethral muscles. When we feel the inclination to evacuate the bladder, and do not wish to obey it, the same muscles,—levatores ani, acceleratores urinæ, and the fibres around the membranous portion of the urethra and neck of the bladder,—are thrown into contraction, and resist that of the bladder.

Such is the ordinary mechanism of the excretion of urine. The contraction of the bladder is, however, of itself sufficient to expel its contents. M. Magendie[1] affirms, that he has frequently seen dogs pass urine when the abdomen was opened, and the bladder removed from the influence of the abdominal muscles; and he further states, that if, in a male dog, the bladder, with the prostate and a small portion of the membranous part of the urethra, be removed from the body, the bladder will contract after a few moments, and project the urine, with an evident jet, until it is entirely expelled.

Urine, voided in the morning—*urina sanguinis*—by a person who has eaten heartily, and taken no more liquid than sufficient to allay thirst, is a transparent, limpid fluid, of an amber colour, saline taste, and peculiar odour. Its specific gravity is estimated by M. Chossat at from 1·001 to 1·038; by Cruikshank, Wagner,[2] and Gregory, from 1·005 to 1·033; by Prout, from 1·015 to 1·025; by Christison,[3] on the average, 1·024 or 1·025; by F. d'Arcet, from 1·001 to 1·060 [?];[4] by Rayer,[5] and Donné,[6] on the average, 1·018; by Dr. Bostock, M. Martin Solon,[7] and J. Vogel, 1·020; by Dr. Routh,[8] 1·021; by Becquerel and Rodier,[9] in man, 1·018·900; in woman, 1·015·120; general average, 1·017·010; by Dr. Elliotson,[10] from 1·015 to 1·025; by Simon, 1012; and

[1] Précis, ii. 474. [2] Elements of Physiology, by R. Willis, § 200, Lond., 1842.

[3] On Granular Degeneration of the Kidneys, p. 34, Edinb., 1839; or Amer. Med. Library edit., Philad., 1839.

[4] L'Expérience, No. lv., Aug., 1838.

[5] Traité des Maladies des Reins, &c., tom. i., Paris, 1839.

[6] Cours de Microscopie, p. 226, Paris, 1844.

[7] De l'Albuminurie ou Hydropisie Causée par Maladie des Reins, Paris, 1838.

[8] Lond. Med. Gaz., Sept., 1850. See, also, Geo. Johnson, on the Diseases of the Kidney, p. 43, Lond., 1852.

[9] Traité de Chimie Pathologique Applique à la Médecine Pratique, p. 270, Paris, 1854.

[10] Human Physiology, p. 293, Lond., 1835.

Dr. Thomson[1] found it in an individual, from 50 to 60 years of age and in perfect health, on the average, 1·013; the lowest specific gravity, during ten days, being 1·004; and the highest, 1·026. Dr. Thomson has published tables[2] showing the quantity of urine passed at different times during ten days by the individual in question, and the specific gravity of each portion. They do not accord with the opinion generally but erroneously entertained, that the heaviest urine is voided on rising in the morning,—*urina sanguinis*. No generalization can, indeed, be made on the subject. The temperature of the urine, when recently passed, varied in one case from 92° to 95°. Dr. Brown-Séquard, however, found its ordinary degree to be 102°·5.[3]

Urine, when first passed, is slightly acid, for it reddens vegetable blues. Although at first transparent, it deposits an insoluble matter on standing; so that that which is passed at bed-time, is found to have a light cloud—*enæorema*—floating in it by the following morning. This substance consists, in part, of mucus from the urinary passages; and, in part, of the super-lithate of ammonia, which is much more soluble in warm than in cold water. Urine is extremely prone to decomposition. When kept for a few days it acquires a strong smell, which, being *sui generis*, has been called *urinous;* and as the decomposition proceeds, it becomes extremely disagreeable. As soon as these changes commence, it ceases to have an acid reaction. In a short time, a free alkali makes its appearance; and a large quantity of carbonate of ammonia is generated, and earthy phosphates are deposited. These phenomena are owing to the decomposition of urea, which is almost wholly resolved into carbonate of ammonia.

Dr. Golding Bird,[4] states, that three distinct varieties of urinary secretion may be recognised. *First.* That passed some little time after drinking freely of fluids, which is generally pale, and of low specific gravity—1·003 to 1·009—*urina potûs*. *Secondly.* That secreted after the digestion of a full meal, varying much in physical characters, and of considerable density—1·020 to 1·028, or even 1·030—*urina chyli* seu *cibi*. *Thirdly.* That secreted from the blood independently of the immediate stimulus of food and drink, as that passed after a night's rest—*urina sanguinis*, which is usually of average density—1·015 to 1·025—and presents in perfection the essential characters of the fluid.

According to Vogel,[5] a healthy man may, by very copious water drinking, reduce the specific gravity of his urine to 1·000·5; and by abstaining from fluids, and by taking such violent exercise as to induce free perspiration may raise it to 1·033, and even more.

The following table, drawn up, as far as 1032, by M. Becquerel, and completed from the observations of the last mentioned inquirer,[6] exhibits at a single inspection the amount of solids and water present in 1000 grains of urine of any particular density; so that from the quan-

[1] British Annals of Medicine, p. 5, Jan., 1837.
[2] Op. citat., p. 6.
[3] Med. Examiner for Sept., 1852, p. 556.
[4] Urinary Deposits, 2d Amer. edit., p. 31, Philad., 1851.
[5] Archiv. d. Vereins für Gemeinschaftlich. Arbeiten, Bd. 1, Heft 1, Göttingen, 1853; cited by Dr. Geo. E. Day, in Brit. and For. Med.-Chir. Rev., July, 1855, p. 73.
[6] Lond. Med. Gazette, Feb. 10, 1843, p. 678.

tity of urine passed in twenty-four hours it is easy to calculate how much solid matter the patient is parting with in that period.

Density.	Water in 1000 grains.	Solids in 1000 grains.	Density.	Water in 1000 grains.	Solids in 1000 grains.
1001	998·35	1·65	1029	960·4	39·6
1002	996·7	3·3	1026	957·1	42·9
1004	993·4	6·6	1028	953·8	46·2
1006	990·1	9·9	1030	950·5	49·5
1008	986·8	13·2	1032	947·2	52·8
1010	983·5	16·5	1034	943·9	56·1
1012	980·2	19·8	1036	940·6	59·4
1014	976·9	23·1	1038	937·3	62·7
1016	973·6	26·4	1040	934·	66·
1018	970·3	29·7	1042	930·7	69·3
1020	967·	33·	1044	927·4	72·6
1022	963·7	36·3	1046	924·1	75·9

The appearances presented by the urine under the microscope have, of late years, given rise to numerous investigations: these of course vary, according to the modifications it exhibits in health and disease. In the latter condition, much information has been collected, so that, according to M. Donné, the study of the urine may be said to be "the triumph of the microscope."[1] The morbid appearances, however, which it presents, do not belong to a work on physiology.

Dr. Henry[2] affirms, that the following substances have been satisfactorily proved to exist in healthy urine,—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatin, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluoride of calcium, chloride of sodium, phosphate of soda, phosphate of ammonia, sulphur and silex. One of the most elaborate analyses has been given by Berzelius.[3] He states it to consist—in 1000 parts—of water, 933·00; urea, 30·10; sulphate of potassa, 3·71; sulphate of soda, 3·16; phosphate of soda, 2·94; chloride of sodium, 4·45; phosphate of ammonia, 1·65; muriate of ammonia, 1·50; free lactic acid; lactate of ammonia; animal matter soluble in alcohol, and urea not separable from the preceding, 17·14; earthy phosphates, with a trace of fluoride of calcium, 1·00; lithic acid, 1·00; mucus of the bladder, 0·32; silex, 0·03. Dr. Prout[4] found 100 parts to consist of lithic acid, 90·16; potassa, 3·45; ammonia, 1·70; sulphate of potassa, with a trace of chloride of sodium, ·95; phosphate of lime, carbonate of lime, and magnesia, ·80; and animal matter, consisting of mucus and a little colouring matter, 2·94. M. Raspail[5] thinks it "possible" that uric acid is merely a mixture of organic matter (albumen) with an acid cyanide of ammonia; so that the results of analysis may differ according as the analyzed substances may have been more or less

[1] Cours de Microscopie, p. 213, Paris, 1844.
[2] Elements of Experimental Chemistry, 9th edit., vol. ii. p. 435, Lond., 1823.
[3] Med.-Chirurg. Transact., vol. iii.; Annals of Philos., ii. 423; and The Kidneys and Urine, by J. J. Berzelius, translated from the German, by M. H. Boyé, and F. Leaming, M. D., p. 97, Philad., 1843.
[4] Annals of Philos., v. 415.
[5] Op. citat., p. 507.

separated from the organic matter. The physical and chemical characters of true uric acid, he thinks, accord very well with this hypothesis.

Elaborate researches have been undertaken by Liebig,[1] as regards the constitution of the urine,—whence he derives the following inferences. *First.* Neither lactic acid nor any lactate exists in healthy urine. *Secondly.* Hippuric acid is a constant constituent. *Thirdly.* The acid reaction of healthy urine is due to the presence of acid phosphate of soda. *Fourthly.* The acidity of urine is maintained and increased by the following changes. The urine of man and the carnivora has a large quantity of sulphates; but their food does not contain either those salts ready formed, or any oxygen compound of sulphur. The sulphur which it does contain, or which amounts to the same thing, the sulphur of the transformed tissues must, therefore, combine with oxygen in the body; and the sulphuric acid thus formed, uniting with part of the alkali of the alkaline phosphates, forms acid phosphates. *Lastly.* It follows, that whether the urine be acid or not depends upon the nature and quantity of the bases taken with the food. If the amount be sufficient to neutralize the uric, hippuric, and sulphuric acids formed by the organism, and the acids supplied by the food, the urine must be neutral; if the amount be more than enough, the urine must be alkaline; if less, acid. Hence no physiological or pathological inference can be drawn from an examination of the urine, unless an account be taken of the inorganic acids, salts, and bases taken with the food. Some experiments have been made on the variations of the acidity of the urine in health by Dr. H. Bence Jones.[2] When a mixed diet was employed, the acidity of the urine was found to decrease soon after taking food, and to attain its lowest limit from three to five hours after meals. It then gradually increased, and attained its highest limit just before taking food. When animal food only was taken, the diminution of acidity was more marked and more lasting; but the acidity before food did not rise quite so high as it did with the animal diet. When vegetable food was alone taken, the decrease in acidity was not to the same degree.

Notwithstanding the view of Liebig, that the uric acid of the urine is held in solution by the phosphate of soda, combining with a part of the base, and setting free a portion of the phosphoric acid, Dr. Golding Bird[3] adheres to the opinion of Dr. Prout, that uric acid is combined with ammonia. "Uric acid," he says, "at the moment of separation from the blood, meets the double phosphate of soda and ammonia derived from the food, and forms urate of ammonia, evolving phosphoric acid, which thus produces the natural acid reaction of the urine."

Healthy urine has been analyzed by Becquerel, Lehmann, Simon, Marchard, Day, and others. The analyses of Lehmann and Marchard approximate that of Berzelius; whilst those of Becquerel, Simon, and Day, agree pretty closely with each other.[4] The following are two of Simon's analyses:—

[1] Annalen der Chemie und Pharmacie, Mai, cited in London Lancet, June 1–8, 1844.
[2] Philosophical Transactions for 1849, Pt. 2.
[3] Urinary Deposits, p. 48.
[4] Dr. Day's Report on Physiological and Pathological Chemistry, in Ranking's Abstract, Part i. p. 283, Amer. edit., New York, 1845.

	I.	II.
Water,	963·00	956·000
Solid constituents,	36·20	44·00
Urea,	12·46	14·578
Uric acid,	0·52	0·710
Alcohol extract and lactic acid,	5·10	4·800
Spirit extract,	2·60	5·593
Water extract and mucus,	1·00	2·550
Lactate of ammonia,	1·03	
Chloride of ammonium,	0·41	
Chloride of sodium,	5·20	7·280
Sulphate of potassa,	3·00	3·508
Phosphate of soda,	2·41	2·330
Earthy phosphates,	0·58	0·654
Silica,	a trace	a trace.

M. Becquerel's analysis,[1] which has been adopted by Dr. Prout,[2] and by Dr. Golding Bird,[3] is as follows:—

Water,		967
Urea,		14·230
Uric acid,		·468
Colouring matter, Mucus and animal extractive matter,	inseparable from each other,	10·167
Salts. Sulphates,	Soda, Potash,	
Biphosphates,	Lime, Soda, Magnesia, Ammonia,	8·135
Chlorides,	Sodium, Potassium,	
Hippurate of soda,		
Fluoride of potassium,		
Silica,		traces
		1000·000[4]

The yellowish-red incrustation, deposited on the sides of chamber utensils, is chiefly urate of ammonia. This is the basis of one of the varieties of calculi.

The following is the proportion, which each principal constituent bears to 100 of solid residuum, according to different observers.[5]

	Berzelius.	Lehmann.	Simon.	Marchard.
Urea,	45·10	49·68	33·80	48·91
Uric acid,	1·50	1·61	1·40	1·59
Extractive matter, ammonia salts and chloride of sodium,	36·30	28·95	42·60	32·49
Alkaline sulphates,	10·30	11·58	11·14	10·18
Alkaline phosphates,	6·88	5·96	6·50	4·57
Phosphates of lime and magnesia,	1·50	1·97	1·59	1·81

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[1] Sémeiotique des Urines, p. 7, Paris, 1841. An analysis of the urine of the two sexes is given by him in his Traité de Chimie Pathologique Appliquée à la Médecine, p. 270, Paris, 1854; and an elaborate analysis after M. Robin is given in Béraud, Manuel de Physiologie de l'Homme, p. 232, Paris, 1853.

[2] On the Nature and Treatment of Stomach and Renal Diseases, 4th edit., Amer. edit., p. 404, Philad., 1843.

[3] Urinary Deposits, Amer. edit., p. 44, Philad., 1845.

[4] See art. Urine, by Dr. Geo. Rees, in Cycl. of Anat. and Phys., iv. 1272, Lond., 1852.

[5] Carpenter, Principles of Human Physiology, Amer. edit., p. 391, Philad., 1854.

The quantity of urine passed in the twenty-four hours is variable. Boissier states it at 22 ounces; Hartmann at 28; Dr. Robert Willis[1] at from 30 to 40; Prout at about 30 in summer, and 40 in winter; Robinson at 35; Von Gorter at 36; Keill at 38; Rye at 39; Bostock at 40; Sanctorius at 44; Stark at 46; Dalton at 48½; Haller at 49; Christison at from 35 to 50; Becquerel at about 46; Dr. Thomas Thomson at 53; Vogel at about 54, and Lining at from 56 to 59 ounces. On the average, it may be estimated perhaps at two pounds and a-half; hence the cause of the great size of the renal artery, which, according to the estimate of Haller, conveys to the kidney a sixth or eighth part of the whole blood. Its quantity and character differ according to age, and, to a certain extent, according to sex. We have already seen, under the head of *cutaneous exhalation*, how it varies, according to climate and season; and it is influenced by the serous, pulmonary, and areolar exhalations likewise: one of the almost invariable concomitants of dropsy is diminution of the renal secretion. Its character, too, is modified by the nature of the substances received into the blood. Rhubarb, turpentine, and asparagus, for example, alter its physical properties; whilst certain articles stimulate the kidney to augmented secretion, or are "diuretics."

The renal secretion may be considered as arising from different sources. When much fluid is taken, the amount of the urine is largely augmented, so that it is manifestly intended to remove superfluous fluid from the blood. It is also, as just shown, materially modified by certain ingesta; and not unfrequently the character of the food taken may be detected in it; hence, it has been conceived, the kidneys may have the duty of removing from the system any crude or undigested elements of the food, which had been absorbed whilst traversing the small intestine, and entered the circulating mass; and of excreting the often noxious results of imperfect or unhealthy assimilation. Lehmann[2] instituted a series of experiments on himself, which afforded interesting information in regard to the varying composition of the urine, according as an animal, a vegetable, a mixed, or a non-nitrogenized diet was employed. On the mixed diet he lived fifteen days; ate and drank moderately; and abstained from all fermented liquors. He took an exclusively animal diet for twelve days, consuming thirty-two eggs each day. A purely vegetable diet was also continued for twelve days; but the non-nitrogenized was only taken for two days. In the following table the quantities of solid matter passed daily are represented by grammes (about 15½ grains troy each); and also the proportional amount of salts and animal matter in that quantity of solid matter.

	Solid matter.	Urea.	Uric acid.	Uric salts.	Extractive matters.
Mixed diet . .	67·82	32·498	1·183	2·257	10·489
Animal diet . .	87·44	53·198	1·478	2·167	5·145
Vegetable diet . .	59·24	22·481	1·021	2·669	16·499
Non-nitrogenized diet	41·68	15·408	0·735	5·276	11·854

[1] Urinary Diseases and their Treatment, Bell's Library edit., p. 14, Philad., 1839.

[2] L'Expérience, 7 Dec., 1843; cited in Edinb. Med. and Surg. Journal, April, 1844, and Art. Harn, Handwörterbuch der Physiologie, 7te Lieferung, S. 16, Braunschweig, 1844; and Lehrbuch der Physiolog. Chemie, ii. 447, Leipzig, 1850; or Amer. edit. of Dr. Day's translation by Dr. Robt. E. Rogers, ii. 163, Philad., 1855.

Lehmann's results certainly show;—*first*, that animal food increases the solid matters in the urine, whilst vegetable substances, and especially non-nitrogenized aliments, diminish them:—*secondly*, that the proportion of nitrogen in the urine depends in part upon the kind of food taken,—food rich in nitrogen greatly increasing its amount. In his experiments, the proportion of urea to the other solid matters was as 100 to 116 under a mixed diet; as 100 to 63 under an animal diet; as 100 to 156 under a vegetable diet; and as 100 to 170 under a non-nitrogenized diet: *thirdly*, that the proportion of uric acid in the urine did not appear to have reference to the kind of food:—*fourthly*, that the urine contained quantities of sulphates and phosphates proportioned to the quantity of nitrogenized matters that had been absorbed: and, *fifthly*, that under an animal diet the quantity of extractive matters diminishes; whilst it is increased by the use of vegetable diet. These extractive matters contained, according to the researches of Liebig,[1] *kreatine* and *kreatinine*, two substances presumed to be derived from the metamorphosis of muscular tissues, and also a peculiar colouring matter derived probably from the hematin of the blood. Experiments by Dr. H. Bence Jones[2] confirm those of Lehmann in certain respects. They show, that all food causes an increase in the amount of uric acid excreted; but that there is no great difference between animal and vegetable food in the production of such increase.

The urine does not appear to be intended for any local function. Its use seems to be restricted to the removal from the blood of the elements of the substances of which it is composed; hence, it is solely depuratory and decomposing. How this decomposition is accomplished we know not. We have already referred to the experiments, performed by MM. Prévost and Dumas, Ségalas, Gmelin, Tiedemann and Mitscherlich, in which urea was found in the blood of animals whose kidneys had been extirpated: an inquiry has consequently arisen—how it exists there? Prior to these experiments, it was universally believed, that its formation is one of the mysterious functions executed in the intimate tissue of the kidney. It is proper to add, however, that neither MM. Prévost and Dumas, Tiedemann and Gmelin, nor M. Lecanu[3] could detect the smallest trace of this substance in the blood of animals placed under ordinary circumstances. It is now, however, admitted, that it exists there normally, but in very small quantity. It is, according to Wöhler and Raspail, a cyanate of ammonia, and contains a very large proportion of nitrogen.

The kidney is the outlet for an excess of nitrogen in the system in the same manner as the lungs and liver are outlets for superfluous carbon. The quantity of nitrogen, discharged in the form of urea, is so great, even in those animals whose food does not essentially contain this element, that it has been conceived a necessary ingredient in the nutrition of parts, and especially in the formation of fibrin, which is a chief constituent of the blood, and of every muscular organ. The remarks made on the absorption of nitrogen during respiration indicate one mode in which it is received into the system; and it has been

[1] Chemistry of Food, Lond., 1847.
[2] Philosophical Transactions, Pt. 2, for 1849.
[3] Études Chimiques sur le Sang Humain, Paris, 1837.

presumed, that the superfluous portion is thrown off in the form of urea.

There are three great modes in which the nitrogen thrown off by the urine may be obtained: *first*, from the air of respiration; *secondly*, from the food; for compounds of protein are absorbed from the intestinal canal; and the nitrogen which is not required for the wants of the system is thrown off from the kidneys in the form of urea and uric acid; and *thirdly*, in the disintegration of the tissues constantly occurring in the system of nutrition. Whilst certain of the elements that are superfluous are thrown off by the lungs and liver, the kidneys separate and throw off the superfluous nitrogen. From the results of Dr. Lehmann's experiments, it has been inferred, that so long as the ingesta contain no nitrogen, the whole of that element in the urine must be attributed to the disintegration or waste of the tissues, and may fairly be taken as a measure of its amount. This, however, is by no means established. We have no positive proof that the nitrogen received into the circulation in respiration is foreign to the formation of the nitrogenized compounds contained in the urine. It has been found in the urine of man after long fasting; and in that of reptiles, which had not taken food for months. Besides serving as an outlet for the superfluous nitrogen, there is no question, that the excess of the sulphur and phosphorus, which have become oxidized in the organism, and converted into sulphates and phosphates by a union with bases, is removed from the system through the urinary secretion.

The whole subject of the urine in its chemical and chemico-physiological, and chemico-pathological history is full of interest; and hence the attention paid to it at this time everywhere by the chemists especially, who have sufficiently shown that the determination of its exact constitution is one of the most abstruse subjects of organic chemistry.[1]

The removal of the constituents of the urinary secretion from the blood is all-important. Experiments on animals have shown, that if it be suppressed by any cause for about three days, death usually supervenes, and the dangers to man are equally imminent. Yet there are some strange cases of protracted suppression on record. Haller mentions a case in which no urine had been secreted for twenty-two weeks; and Dr. Richardson,[2] one of a lad of seventeen, who had never made any, and yet felt no inconvenience.

a. *Connexion between the Stomach and Kidneys.*

In consequence of the rapidity with which fluids received into the stomach are sometimes voided by the urinary organs, it has been imagined, either that vessels exist, which communicate directly between

[1] For the recent investigations of R. Bunsen, Millon, Marchard, Allan and Bensch, ·nard and Barreswil, Strahl and N. Lieberkühn, Wöhler and Frerichs, &c., see ·rer, in Canstatt and Eisenmann's Jahresbericht über die Fortschritte in der Bio-·gie im Jahre, 1848, S. 88; W. Marcet, in a Notice of the Traité de Chimie Anatomique, &c., of Robin and Verdeil, in Brit. and For. Medico-Chir. Rev., April, 1853, p. 358; and for the investigations of Prof. J. Vogel, Dr. Fr. Beneke and others; see Gerber, Ibid., for July, 1855, p. 71; Becquerel and Rodier, Traité de Chimie Pathologique, &c., p. 267, Paris, 1854, and Lehmann, Lehrbuch der Physiologischen Chemie, S. 387, Leipz., 1850; or Amer. edit. of Dr. Day's translation by Dr. Robt. E. Rogers, ii. 106, Philad., 1855.

[2] Philos. Transact. for 1713.

the stomach and bladder, or that the fluid passes through the intermediate areolar tissue, or through the anastomoses of lymphatics. Experiments of Mr. Erichsen,[1] which consisted in introducing certain substances, that are readily detected by appropriate tests, into the stomach, and noting their appearance in the urine, signally exhibit the rapidity of this transmission. The earliest period at which prussiate of potassa was detected was about one minute after being swallowed; and the longest, thirty-nine minutes,—the difference appearing to depend upon the presence or absence of food in the stomach at the time. When it was empty, the salt was discovered in from one to two and a half minutes; whilst soon after a meal it required from six and a half to thirty-nine minutes.

In support of the opinion, that a more direct passage exists, the assertion of M. Chirac,—that he saw the urinary bladder become filled with urine when the ureters were tied, and that he excited urinous vomiting by tying the renal arteries,—is brought forward. It has been farther affirmed, that the oil, composing a glyster, has been found in the bladder. Dr. Darwin,[2] having administered to a friend a few grains of nitrate of potassa, collected his urine at the expiration of half an hour, and had him bled. The salt was found in the urine, but not in the blood. Mr. Brande made similar experiments with prussiate of potassa, from which he inferred, that the circulation is not the only medium of communication between the stomach and urinary organs, without, however, indicating the nature of the supposed medium; and this view is embraced by Sir Everard Home,[3] and Drs. Wollaston, Marcet, and others. Lippi,[4] of Florence, thinks he has found an anatomical explanation of the fact. According to him, the chyliferous vessels have not only numerous inosculations with the mesenteric veins, either before their entrance into the mesenteric glands, or whilst they traverse those organs; but, when they attain the last of them, some proceed to open directly into the renal veins, and into the pelves of the kidneys. At this place, according to him, the chyliferous vessels divide into two sets; the one, ascending, and conveying the chyle into the thoracic duct; the other, descending, and carrying drinks into the renal veins and pelves of the kidneys. He affirms, that the distinction between the two sets is so marked, that an injection sent into the former goes exclusively into the thoracic duct, whilst if it be thrown into the latter it passes exclusively to the kidneys. These direct vessels Lippi calls *vasa chylopoietica urinifera*.

A kindred and equally inconceivable view has been recently maintained by M. C. Bernard,[5] who affirms, that when he introduced prussiate of potassa into the intestine of an animal, he recognized it sooner in the renal vein than in the renal artery. To account for this he instituted a series of researches, from which he concludes, that liquids

[1] Dublin Medical Press, July 9, 1845, and Ranking's Abstract, Part ii. p. 241, Amer. edit., New York, 1846.

[2] Zoonomia, xxix. 3.

[3] Philosophical Transactions, xcviii. 51, and ci. 163, for 1808 and 1811; and Lectures on Comparative Anatomy, i. 221, Lond., 1814; and iii. 138, Lond., 1823.

[4] Illustrazioni Fisiologiche e Patologiche del Sistema Linfatico-Chilifero, &c., Firenz, 1825.

[5] Union Médicale, No. 116, cited in British and Foreign Medico-Chirurgical Review, for Jan., 1850, p. 246.

absorbed from the intestines, after passing through the portal system and arriving in the vena cava, instead of ascending towards the heart, descend into the renal veins, which convey them to the renal capillaries; so that a considerable portion of them is eliminated without passing into the general current of the circulation.

In regard to the assertions of Lippi, were they anatomical facts, it would obviously be difficult to doubt some of the deductions; other anatomists have not, however, been so fortunate as he; and, consequently, it may be well to make a few comments. Yet—as has been elsewhere seen—the communication between the abdominal lymphatics and veins has been maintained by Dr. Nuhn.[1] Some of these chylopoietica urinifera, Lippi affirms, open into the renal veins. This arrangement, it is obvious, cannot be invoked to account for the shorter route—the *royal road* to the kidney. The renal vessel conveys the blood back *from* the kidney, and every thing that reaches it from the intestines must necessarily pass into the vena cava, and ultimately attain the kidney through the renal artery. The vessels, therefore, that end in the renal veins, must be put entirely out of the question, so far as regards the topic in dispute; and attention be concentrated upon those that terminate in the pelvis of the kidney. Were this termination proved, we should be compelled, as we have remarked, to bow to facts; but not having been so, it may be stated as seemingly improbable, that the ducts in question should take the circuitous course to the pelvis of the kidney, instead of the direct one to the bladder.

We know, then, nothing anatomically of any canal between the stomach and bladder; and have not the slightest evidence—positive or relative—in favour of the opinion, that there is any transmission of fluid through the intermediate areolar tissue. There is, indeed, absolute testimony against it. MM. Tiedemann and Gmelin having examined the lymphatics and areolar tissue of the abdomen, in cases where they had administered indigo and essence of turpentine to animals, discovered no traces whatever of them, whilst they could be detected in the kidney. The *facts*, again, referred to by Chirac, are doubtful. If the renal arteries be tied, the secretion cannot be effected; yet, as we have seen, in the case of extirpated kidneys, urea may exist in the blood, and, consequently, urinous vomiting be possible. If the ureters be tied, the secretion being practicable, death will occur if the suppression be protracted; and, in such case, the secreted fluid may pass into the vessels, and readily give a urinous character to the perspiration, vomited matters, &c., &c. The experiments of Darwin, Brande, Wollaston, and others only demonstrate, that these gentlemen were unable to detect in the blood that which they found in the urine. Against the *negative* results attained by these gentlemen, we may adduce the positive testimony of M. Fodéra,[2] an experimentalist of weight, especially on those matters. He introduced into the bladder of a rabbit a plugged catheter, and tied the penis upon the instrument to prevent the urine from flowing along its sides. He then injected into the stomach a solution

[1] Page 241.

[2] Recherches Expérimentales sur l'Absorption et l'Exhalation, Paris, 1824.

of ferrocyanuret of potassium. This being done, he frequently removed the plug of the catheter, and received the drops of urine on filtering paper. As soon as indications of the presence of the salt appeared in the urine by the appropriate tests,—which usually required from five to ten minutes after its reception into the stomach,—the animal was killed; and on examining the blood, the salt was found in the serum taken from the thoracic portion of the vena cava inferior, right and left cavities of the heart, aorta, thoracic duct, mesenteric glands, kidneys, joints, and mucous membrane of the bronchia. M. Magendie,[1] too, states, as the result of his experiments,—*First.* That whenever prussiate of potassa is injected into the veins, or is exposed to absorption in the intestinal canal, or in a serous cavity, it speedily passes into the bladder, where it can be readily recognised in the urine. *Secondly.* That if the quantity of prussiate injected be considerable it can be detected in the blood by reagents; but if it be small, it is impossible to discover it by the ordinary means. *Thirdly.* That the same thing happens if the prussiate of potassa be mixed with the blood out of the body. *Fourthly.* That the salt can be detected in the urine in every proportion.

We may conclude, therefore, with Dr. Hale,[2] who has written an interesting paper on this subject, that the existence of any more direct route from the stomach to the bladder than the circulatory system and the kidneys is disproved; and we must consider the absorption of fluids to be effected through the vessels described under Absorption of Drinks. The facts, referred to elsewhere, (p. 437,) which show the extreme rapidity of the circulation, materially facilitate our comprehension of these cases.

Such are the glandular secretions to be considered in this place. There are still two important secretions—

7. *Secretion of the Testes,*

and

8. *Secretion of the Mammæ,*

which will be investigated under the Functions of Reproduction.

IV. VASCULAR OR DUCTLESS GLANDS.

There are several organs,—as the spleen, thyroid, thymus, and supra-renal capsules,—which are termed glands—*vascular glands, blood,* or *ductless glands,* by many anatomists; but by M. Chaussier *glandiform ganglions.* Of the uses of these we know little. Yet it is necessary that the nature of the organs and their presumed functions should meet with notice. The offices of the thyroid, thymus, and supra-renal capsules,—being chiefly confined to fœtal existence,—will not require consideration here. Although they have no ducts, their minute arrangement greatly resembles that of the true glands; and they are all perhaps concerned, in some manner, in hæmatosis or the due elaboration of the circulating fluid.[3] It has been elsewhere seen, that the

[1] Précis, &c., ii. 477.
[2] Boylston Prize Dissertation for the years 1819 and 1821. Boston, 1821.
[3] See, on the whole subject of the vascular glands, Ecker's elaborate article Blutgefässdrüsen, in Wagner's Handwörterbuch der Physiologie, iv. 107, Braunschweig, 1853.

glands of Peyer may be classed under this head; and Ecker adds the pituitary gland of the brain.[1]

a. *The Spleen.*

The *spleen* is a viscus of considerable size, situate in the left hypochondriac region (Fig. 155), beneath the diaphragm, above the left kidney, and to the left of the stomach. Its medium length is about four and a half inches; its thickness two and a half, and its weight about eight ounces.[2] Its absolute weight, and its weight in proportion to that of the whole body, increases rapidly, according to Huschke, after birth; and its proportionate weight soon attains its highest standard, so that, in the adult, it has not a decidedly greater proportion to the body than at birth; and in some cases even decreases. It varies between 1 to 235 and 1 to 240.[3] Its relation to the weight of the liver is proportionally greater in the adult than in the infant. It is of a soft texture, somewhat spongy to the feel, and easily torn; and in a very recent subject is of a grayish-blue colour; which, in a few hours, changes to purple, so that it resembles a mass of clotted blood. At its inner surface, or that which faces the stomach and kidney, a fissure exists, by which the vessels, nerves, &c., enter or issue from the organ.

The histology of the spleen has been much investigated of late. Its main anatomical elements have been considered to be:—1. The *splenic artery*, which arises from the cœliac, and after having given off branches to the pancreas and the left gastro-epiploic artery divides into several branches, which enter the spleen at the fissure, and ramify in the tissue of the organ; so that it seems to be exclusively formed by them. Whilst the branches of the artery are still in the duplicature of the gastro-splenic omentum, and before they ramify in the spleen, they furnish the vasa brevia to the stomach. The precise mode of termination of the arteries in the spleen is unknown: their communication with the veins does not, however, appear to be as free as in other parts of the body, nor the anastomoses between the minute arteries as numerous. If, according to Assolant,[4] one of the branches of the splenic artery be tied, the portion of the spleen to which it is distributed dies; and if air be injected into one of these branches, it does not pass into the other; so that the spleen would appear to be a congeries of several distinct lobes; and in certain animals the lobes are so separated as to constitute several spleens. A similar appearance is occasionally seen in the human subject. 2. The *splenic vein* arises by numerous radicles in the tissue of the spleen: these become gradually larger, and less numerous, and leave the fissure of the spleen by three or four trunks, which ultimately unite with veins from the stomach and pancreas to form one, that opens into the vena porta. It is without valves, and its parietes are thin. These are the chief constituents. 3. *Lymphatic vessels*, which are large and numerous. 4. *Nerves*, proceeding from the cœliac plexus: they creep along the coats of the splenic artery—upon which they form an

[1] Op. cit., S. 160.

[2] Gross, Elements of Pathological Anatomy, 2d edit., p. 674, Philad., 1845.

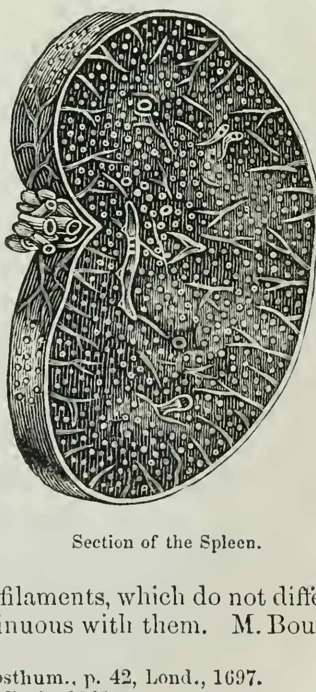
[3] The French translation of Jourdan says between 1 to 235 and 1 to 400,—Encyclop. Anatom., v. 172, Paris, 1845.

[4] Recherches sur la Rate, Paris, 1801.

intricate plexus—into the substance of the spleen. 5. *Areolar tissue*, which serves as a bond of union between these various parts; but is in extremely small quantity. 6. A *proper membrane*, which envelopes the organ externally; adheres closely to it, and furnishes fibrous sheaths to the ramifications of the artery and vein; keeping the ramifications separated from the tissue of the organ, and sending prolongations into the parenchyma, which gives it more of a reticulated than a spongy aspect. 7. Of *blood*, according to many anatomists; but blood differing from that of both the splenic artery and vein,—*boue splénique*, containing, according to M. Vauquelin, less colouring matter and fibrin, and more albumen and gelatin, than any other kind of blood. This, by stagnating in the organ, is conceived to form an integrant part of it. Malpighi[1] believed it to be contained in cells; but others have supposed it to be situate in a capillary system intermediate between the splenic artery and vein.

Assolant and Meckel[2] believe, that the blood is in a peculiar state of combination and of intimate union with the other organic elements of the viscus, and with a large quantity of albumen; and that this combination of the blood forms the dark brown pulpy substance, contained in the cells formed by the proper coat, and which can be easily demonstrated by tearing or cutting the spleen, and scraping it with the handle of a knife. These cells and the character of the tissue of the spleen are exhibited in the marginal figure (Fig. 182). In addition to the pulp, there is an abundance of rounded corpuscles, varying in size from an almost imperceptible magnitude to a line or more in diameter. By Malpighi, these were conceived to be granular corpuscles, and, by Ruysch,[3] simply convoluted vessels. M. Andral[4] affirms, that by repeated washings the spleen is shown to consist of an infinite number of cells, which communicate with each other, and with the splenic veins. The latter, when the inner surface of the large subdivisions of the splenic veins are examined, appear to have a great number of perforations, through which a probe passes directly into the cells of the organ. The farther the subdivisions of the vein examined are from the trunk, the larger are these perforations; and still farther on, the coats of the vein are not a continuous surface, but are split into filaments, which do not differ from those forming the cells, and are continuous with them. M. Bour-

Fig. 182.



Section of the Spleen.

[1] Op. Omnia, pars ii., Lond., 1687; and Op. Posthum., p. 42, Lond., 1697.
[2] Handbuch, &c., traduit par Jourdan, iii. 476, Paris, 1825.
[3] Meckel, op. citat.
[4] Précis d'Anatomie Pathologique, tom. ii. part i. p. 416, Paris, 1832.

gery has maintained, that the fibrous envelope of the spleen sends off a multitude of lamellæ, which penetrate its interior, forming irregular spaces of unequal dimensions. These short spaces he calls *splenic vesicles.* In the septa, a number of lymphatic glands exists. The capillaries of the arteries communicate directly with those of the veins; but, according to M. Bourgery, there are, in addition, veins with patulous orifices. The interior of the vesicles is filled with a soft substance of a deep red colour, in which the small white corpuscles, discovered by Malpighi, are suspended. M. Mandl[1] suggests, that the white corpuscles may be analogous to the intestinal villi, in which the lymphatics originate by a cæcal extremity.

The minute structure of the spleen has been intimately investigated by Dr. Evans,[2] and by Professor Kölliker,[3] and still more recently by Dr. Sanders,[4] Mr. Wharton Jones,[5] Mr. Huxley,[6] Mr. Gray,[7] Günsburg, Führer,[8] and others. The organ, according to Kölliker, is essentially composed of a fibrous membrane, formed of white fibrous tissue, and in many of the lower animals having unstriped muscular fibres intermixed,[9] which constitutes its exterior envelope, and sends trabecular prolongations in all directions across its interior, so as to divide it into a number of irregularly shaped splenic cells, communicating freely with each other and with the splenic vein, and lined by a membrane continuous with that of the vein, which is so reflected upon itself as to leave oval or circular foramina, by which each cell communicates with the others and the vein. The diameter of these cells is estimated at from one-third to half a line, and they are generally traversed by filaments of elastic tissue, imbedded in which a minute artery and vein may frequently be observed. Over these filaments the lining membrane is reflected in folds; so that each cell is thus incompletely divided into two or more small compartments. No direct communication exists between the splenic artery and the interior of the cells; but its branches are distributed through the intercellular parenchyma, and the small veins, which collect the blood from the arterial capillaries of the organ, carry it into the cells whence it is conveyed away by the splenic vein. The cells may be readily injected from the vein with either air or liquid, provided they are not filled

[1] Manuel d'Anatomie Générale, p. 518, Paris, 1843.

[2] Lancet, April 6, 1844.

[3] Mittheilungen der Züricher Naturforschenden Gesellschaft vom Jahre 1847; Art. Spleen, Cyclopædia of Anatomy and Physiology, pts. xxxvi. and xxxvii., June and October, 1849; and Kölliker, Mikroskopische Anatomie, ii. 253, Leipzig, 1852; or Amer. edit. of the translation of his Manual of Histology, by Dr. Da Costa, p. 551, Philad., 1854.

[4] Goodsir's Annals of Anatomy and Physiology, No. 1, p. 49, Feb., 1850.

[5] Brit. and For. Med.-Chir. Rev., Jan., 1853, p. 275.

[6] Quarterly Journal of Microscopical Science, ii. 74, London, 1854; and Kölliker's Manual of Histology, Amer. edit. by Dr. Da Costa, p. 786, Philad., 1854.

[7] The Structure and Use of the Spleen, Lond., 1854.

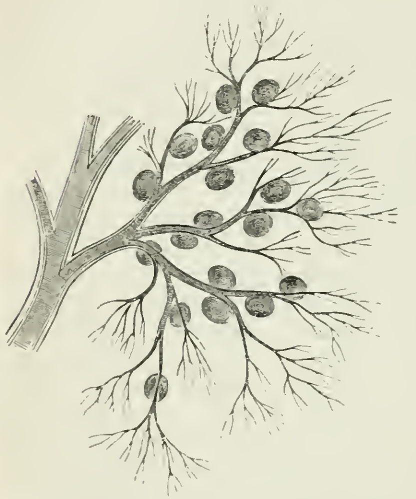
[8] Cited in Canstatt's Jahresbericht, im Jahre 1854, 1er Bd. S. 72.

[9] Sharpey, in Quain and Sharpey's edition of Quain's Human Anatomy, by Leidy, ii. 498, Philad., 1849, Kölliker, op. citat.; and Ecker, art. Blutgefässdrüsen, Wagner's Handwörterbuch der Physiologie, 23ste Lieferung, S. 132, Braunschweig, 1849. Mazoun states that the covering and trabecular tissue of the organ in man contain muscular fibre.—Müller's Archiv., i. 25, Berlin, 1854; and J. W. Ogle, Report on Micrology in Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 530.

with coagulated blood; and they are so distensible—as has been long known—that the organ may be made, with very little force, to dilate to many times its original size. The cells of the spleen, according to Dr. Evans, never contain any thing but blood; and a frequent appearance after death is that of firmly coagulated blood filling them, and giving a granular aspect to the organ, which is sometimes described as morbid. The partitions between the cells are formed by the membranes already mentioned, and by the proper parenchyma of the spleen. To the eye it has a semi-fluid appearance, but when an attempt is made to tear it, considerable resistance is experienced, in consequence of its being intersected by what seem to be minute fibres. When a small portion is pressed, a liquid exudes—*liquor lienis* or splenic blood—which is usually described as filling the cells of the spleen; but according to Dr. Evans this is erroneous. This liquid, when diluted with serum, and examined under the microscope, is found to contain two kinds of corpuscles,—one apparently identical with ordinary blood corpuscles—the other with the corpuscles characteristic of lymph, and abundant in the lymphatic ganglions. The remaining fibrous substance consists wholly of capillary bloodvessels and lymphatics with minute corpuscles, much smaller than blood corpuscles, varying in size from about $\frac{1}{6000}$th to $\frac{1}{7000}$th of an inch, of spherical form, and usually corrugated on the surface. These lie in great numbers in the meshes of the sanguiferous capillaries; and the minute lymphatics are described by Dr. Evans as connected with the splenic corpuscles, and apparently arising from them. Lying in the midst of the parenchyma is a large number of bodies, of about a third of a line in diameter, which are evidently in close connexion with the vascular system. These are the *Malpighian bodies* of the spleen or *splenic corpuscles*. According to Dr. Evans, they, in all respects, resemble mesenteric or lymphatic ganglions in miniature—consisting, as they do, of convoluted masses of bloodvessels and lymphatics, united together by elastic tissue, so as to possess considerable firmness; and they farther correspond with them in this,—that the lymph they contain, which is quite transparent in the afferent vessels, becomes somewhat milky, from containing a large number of lymph corpuscles.

Professor Kölliker describes the spaces left by the trabecular prolongations as of irregular form and size, and occupied by the peculiar *splenic* or *Malpighian corpuscles*, and the splenic parenchyma. These corpuscles, according to him, are whitish spherical bodies, imbedded in the parenchyma of the spleen, but connected with the smaller arteries by short peduncles in a racemose manner. They are seldom seen in the human subject, owing to the rapid changes they undergo after death; but Professor Kölliker has no doubt of their being invariably present in health. He affirms, that they have no relation to the lymphatics; but are closed capsules, resembling the elementary cells of glands before the rupture of their walls. The red *spleen substance*, *spleen pulp* or *parenchyma of the spleen*, consists in great part of cells, which correspond in appearance with those of the Malpighian corpuscles. Two other kinds, however, occur in it seldom met with in the latter; and numerous free nuclei are also present. Of these, one set bears a strong resemblance to red blood corpuscles; the others are pale with one or two nuclei, or colourless granule cells. A considerable part of the pulp appears to consist of blood corpuscles in various stages of metamorphosis, as was first taught by Professor Kölliker. "The blood globules"—he remarks—"first become at once smaller and darker, whilst the elliptical corpuscles of the lower vertebrata also become rounder; then, in connection with some blood plasma, they become aggregated into small round heaps; which heaps, by the appearance of an interior nucleus and of an outer membrane, experience a transition into spherical cells containing blood corpuscles. These are from 5-1000ths to 15-1000ths of a line in size, and contain from one to twenty blood corpuscles. During this time, the blood corpuscles are continually diminishing in size; and, assuming a golden yellow, brownish red or dark colour, they undergo, either immediately, or after a previous dissolution, a complete transition into pigment granules. So that these cells themselves are changed into pigmentary granule cells; and finally, by a gradual loss of colour of their granules, they form themselves into completely colourless cells."[1] These are found in the blood, especially of the splenic vein, vena porta and inferior cava. It is not, however, easy to see how the corpuscles can leave the splenic arteries, unless they have a direct open communication with the splenic pulp, which is not admitted. Professor Kölliker describes the arterial branches as ramifying in the red spleen substance, where each twig subdivides into smaller and smaller arteries, and, when they become capillary, constitute a close and beautiful network in the splenic pulp. Giesker,[2] however, considers that the pulp consists of nothing but the minutest arteries and veins united by fibrous tissue. The whole subject, however, of splenic histology appears to the author to be far from determined, and to demand fresh investigations.

Fig. 183.



Branch of Splenic Artery, the ramifications of which are studded with Malpighian Corpuscles.

Besides the proper membrane, the spleen receives also a peritoneal coat; and, between the stomach and it, the peritoneum forms the *gastro-splenic epiploon* or *gastro-splenic ligament*, in the duplicature of which are situate the vasa brevia. Lastly; the spleen, as remarked above, is capable of distension and contraction; and is possessed of little sensibility in the healthy state. It has no excretory duct.[3]

[1] Art. Spleen, Cyclop. of Anat. and Physiol., &c., p. 782.

[2] Cited by Kölliker. p. 790.

[3] A good epitome of the views of different observers in regard to the structure of the spleen, with observations of his own, is given by Dr. Wm. R. Sanders, op. cit.

The hypotheses, which has been indulged on the functions of the spleen, are beyond measure numerous and visionary; and, after all, we are in much obscurity as to its real uses. Many of these hypotheses are too idle to merit notice; such are those, that consider it to be the seat of the soul;—the organ of dreaming; of melancholy and of laughter, of sleep and the venereal appetite,—the organ that secretes the mucilaginous fluids of the joints; that serves as a warm fomentation to the stomach, and so on. It was long regarded as a secretory apparatus for the formation of atrabilis,—of a fluid intended to nourish the nerves,—of gastric juice,—of a humour intended to temper the alkaline character of the chyle or bile, &c. The absence of an excretory duct would be a sufficient answer to all these speculations, if the non-existence of the supposititious humours were insufficient to exhibit their absurdity. MM. Tiedemann and Gmelin[1] consider its functions to be identical with those of the mesenteric glands. They regard it as a ganglion of the absorbent system, which prepares a fluid to be mixed with the chyle and effect its animalization. In favour of the view, that it is a part of the lymphatic system, they remark, that it exists only in those animals which have a distinct absorbent system;—that its bulk is in a ratio with the developement of the absorbent system;—that the lymphatics predominate in the structure of the organ; that its texture is like that of the lymphatic ganglions; and lastly, that on dissecting a turtle they distinctly saw all the lymphatics of the abdomen passing first to the spleen, then leaving that organ of larger size, and proceeding to the thoracic duct.

In support of their second position, that it furnishes some material towards the animalization of the chyle, they adduce,—the large size of the splenic artery, which manifestly, they conceive, carries more blood to the organ than is needed for its nutrition; and affirm, that, in their experiments, they have frequently found, whilst digestion and chylosis were going on, the lymphatic vessels of the spleen gorged with a reddish fluid, which was carried by them into the thoracic duct, where the chyle always has the most rosy hue; and that a substance injected into the splenic artery passes readily into the lymphatics of the spleen. Lastly, after extirpating the spleen in animals, the chyle appeared to them to be more transparent,—no longer depositing coagula; and the lymphatic ganglions of the abdomen seemed to have augmented in size. Views similar to these had been maintained by Sir Everard Home.[2]

M. Chaussier, as has been seen, classes the spleen amongst the *glandiform ganglions;* and affirms, that a fluid, of a serous or sanguineous character, is exhaled into its interior, which, when absorbed, assists in lymphosis. Many, again, have believed, that it is a sanguineous, not a lymphatic ganglion, but they have differed regarding the blood on which it exerts its action; some maintaining, that it prepares the blood for the secretion of gastric juice; others, for that of the bile. The former of these views is at once repelled by the fact, that the vessels

[1] Versuche über die Wege auf welche Substanzen aus dem Magen und Darmkanal im Blut gelangen, p. 86, Heidelb., 1820.

[2] Philosoph. Transactions for 1808 and 1811; and Lect. on Comp. Anatomy, loc. cit.

which pass from the splenic artery to the stomach, leave that vessel before it enters the spleen. The latter has been urged by M. Voisin.[1] He thinks, the principal use of the spleen is to furnish to the liver blood containing those materials that enter into the composition of the bile; but as to the changes produced on the blood, the greatest difference of sentiment has existed. Mr. Hewson[2] believed, that the spleen is the organ ordained by nature for "the more perfectly forming the red particles of the blood;" a view in which Prof. J. Hughes Bennett and Funke,[3] accord; whilst Professor Kölliker infers from his observations —and Professor Ecker,[4] of Basle, Moleschott, Mr. Gray, and M. Béclard,[5] agree with him,—that they suffer destruction or decomposition in the spleen, becoming changed in the manner before described; but in one that does not seem very intelligible. He supposes, that the altered corpuscles may be inservient to the formation of bile, the colouring matter of which is nearly allied to that of the blood, whilst the small nucleated cells of the Malpighian bodies may be concerned—it has been suggested—in the formation of fibrin.

That some change is effected by the organ upon the blood sent to it by the splenic artery has long seemed to be confirmed by examination of that fluid. Since the period of Haller, the blood of the splenic vein has been presumed to differ essentially from that of other veins, which naturally led to the belief, that some elaboration is effected in the spleen to fit the blood for the secretion of bile. It has been described as more aqueous, albuminous, and unctuous, and blacker than other venous blood; to be less coagulable, less rich in fibrin, and the fibrin it does contain to be less animalized.[?] Yet these affirmations are denied; and even were they admitted, we have no positive knowledge, that such changes adapt it better for the formation of bile. Examinations of the blood of the splenic and other veins by M. Béclard[6] favour the views of Professor Kölliker. The following were the results of an examination of the blood of four successive bleedings of the same animal:—

	External Jugular.	Mammary.	Splenic.	Vena Porta.
Water, ...	778·9	750·6	746·3	702·3
Albumen, . . .	79·4	89·5	124·4	70·6
Red corpuscles and fibrin,	141·72	159·9	128·9	227·1

Farther analyses by the same gentleman showed a manifest diminution of the red corpuscles, and an increase of albumen and fibrin.[7]

The ideas that have existed, in regard to the spleen being a diverticulum for the blood, have been mentioned under Circulation. By some, it has been supposed to act as such in the intervals of digestion; or in other words, to be a diverticulum to the stomach: by others, its

[1] Nouvel Aper u sur la Physiologie du Foie et les Usages de la Bile, Paris, 1833.

[2] Works by Gulliver, Sydenham Society's edit., p. 273, Lond., 1846.

[3] Henle und Pfeuffer's Zeitschr., Bd. i. S. 172; cited in Canstatt's Jahresbericht im Jahre 1851, B. i. S. 136; and Rudolph Wagner's Lehrbuch der speciellen Physiologie, von Otto Funke, 1ste Lieferung, S. 120, Leipz., 1854.

[4] Schmidt's Jahrbücher, u. s. w., No. 5, S. 146, Jahrgang, 1848, and art. Blutgefässdrüsen, in Wagner's Handwörterbuch der Physiologie, 23te Lieferung, S. 152, Braunschweig, 1849; see, also, Dr. W. R. Sanders, Medical Times, April 21, 1849.

[5] Traité Élémentaire de Physiologie, p. 411, Paris, 1855.

[6] Annales de Chimie et de Physique, xxi. 506, Paris, 1847.

[7] Comptes Rendus, xxvi. 122.

agency in this way is believed to apply to the whole circulatory system, so that when the flow of blood is impeded or arrested in other parts, it is received into the spleen. Such a view was entertained by Dr. Rush,[1] and it has been embraced by many others.

It is hard to say which of these speculations is the most ingenious. None can satisfy the judicious physiologist, especially when he considers the comparative impunity consequent on extirpation of the organ. This was an operation performed at an early period. Pliny affirms, that it was practiced on runners to render them more swift. From animals the spleen has been repeatedly removed; and although many of these died in consequence of the operation, several recovered. M. Adelon[2] refers to the case of a man who was wounded by a knife under the last false rib of the left side. Surgical attendance was not had until twelve hours afterwards; and as the spleen had issued at the wound, and was much altered, it was considered necessary to extirpate it. The vessels were tied; the man got well in less than two months, and has ever since enjoyed good health. Sir Charles Bell[3] asserts, that an old pupil had given him an account of his having cut off the spleen in a native of South America. The spleen had escaped through a wound, and had become gangrenous. He could observe no effect from the extirpation. T. Chapman,[4] Esq., of Purneah, in India, has related a case of excision of a portion of the spleen by Dr. Macdonald of that station. A native, about thirty years of age, was gored in the abdomen by a buffalo; and through the wound, which was about three inches in length, a portion of the spleen protruded. Six days afterwards, the man sought advice from Dr. Macdonald, who removed the spleen with a knife, and the patient rapidly recovered.

Dr. O'Brien, in an inaugural dissertation, published at Edinburgh in 1818, refers to a case which fell under his own management. The man was a native of Mexico: owing to a wound of the abdomen, the spleen lay out for two days before the surgeon was applied to. The bleeding was profuse; the vessels and other connexions were secured by ligature, and the spleen separated completely on the twentieth day of the wound. On the forty-fifth day, the man was discharged from the hospital cured; and he remarked to some one about this time, that "he felt as well as ever he did in his life." The case of a man has been reported, who lived in good health for thirteen years after the spleen had been removed;[5] and another by M. Berthet de Gray of a middle-aged man, who received a wound in the side, through which the spleen eventually protruded, and becoming gangrenous was removed. The man recovered, and lived thirteen years, enjoying sound health, his digestion being generally good. After death from pneumonia, all that remained of the spleen was found to be a small portion of the size of a filbert, adhering to the stomach.

[1] Coxe's Medical Museum, Philad., 1807.
[2] Physiol. de l'Homme, 2de édit., tom. iii., Paris, 1829.
[3] Anat. and Physiol., 5th Amer. edit., by Dr. Godman, ii. 363, New York, 1827.
[4] India Journal of Medicine, vol. viii. p. 1; and London Medical Gazette for May 20, 1837, p. 285.
[5] Gazette Médicale de Paris, No. 28, 1844, cited from Oesterreich. Med. Wochenschrift, 21 Sept., 1844.

Dulaurens, Kerckring, Baillie,[1] and others,[2] refer to cases, in which the spleen was wanting in man, without any apparent impediment to the functions; and the author has seen it in the dead body not larger than an almond, when there had been no reason to suspect splenic disease.

The experiments, which have been made on animals, by removing the spleen, have led to discordant results. Malpighi says, that the operation was followed by increased secretion of urine; Dumas, that the animals had afterwards a voracious appetite; Mead and Mayer, that digestion was impaired; that the evacuations were more liquid, and the bile more watery; Tiedemann and Gmelin, that the chyle appeared more transparent and devoid of clot; Professor Coleman, that the dogs,—subjects of the experiment,—were fat and indolent. A dog, whose spleen was removed by Mr. Mayo,[3] became, on recovering from the wound, fatter than before; in a year's time it had returned to its former condition, and no difference was observed in its appearance or habits from those of other dogs. Similar results followed the experiments of Dr. Blundell, Mr. Dobson, and Mr. Eagle;[4] and the last gentleman states, that an offer had been made him of a "smart sum of money" by a dealer in Leadenhall Market, if he would tell him his method of fattening animals.

M. Dupuytren extirpated the spleen of forty dogs on the same day, without tying any vessel, but merely stitching up the wound of the abdomen,—yet no hemorrhage supervened! In the first eight days, half the dogs operated on died of inflammation of the abdominal viscera induced by the operation, as was proved by dissection. The other twenty got well without any accident, at the end of three weeks at the farthest. At first, they manifested a voracious appetite, but it soon resumed its natural standard. They fed on the same aliment, and drinks, took the same quantity of food, and digestion seemed to be accomplished in the same time. The fæces had the same consistence and appearance, and the chyle appeared to have the same character. Nor did the other functions offer any modification. M. Dupuytren opened several of the dogs some time afterwards, and found no apparent change in the abdominal circulation,—in that of the stomach, epiploon, or liver. The last organ, which appeared to some of the experimenters to be enlarged, did not seem to him to be at all so. The bile alone appeared a little thicker, and deposited a slight sediment. Similar experiments by Bardeleben[5] have led to results of an analogous kind. Animals, which survived the extirpation of the spleen, appeared to recover their health speedily, and to present no difference from those which had not undergone the operation. He never remarked, however, that they were more voracious than other animals. In no case was the organ regenerated. An animal deprived of both spleen and thyroid presented no change in any function,—a circumstance,

[1] Morbid Anatomy, 5th edit., p. 277, Lond., 1818.
[2] R. Lebby, Southern Journ. of Med. and Pharmacy, Sept., 1846.
[3] Outlines of Human Physiology, 4th edit., p. 107, Lond., 1838; and Outlines of Human Pathology, p. 128, Lond., 1836.
[4] Lond. Lancet, Oct. 8, 1842, p. 58, and Dec. 10, 1842, p. 406.
[5] Gazette M dicale de Paris, 23 Mars, 1844.

which is in opposition to the view of Tiedemann, that the lymphatic ganglions and thyroid perform the functions of the spleen, when that organ has been extirpated. The incorrectness of the opinion of certain physiologists, that extirpation of the spleen causes augmentation of the venereal appetite, but abolition of the procreative power, was shown by M. Bardeleben, by breeding with dogs from which both spleen and thyroid had been removed.

Professor Mayer, of Bonn,[1] has affirmed that after the extirpation of the spleen, the small lymphatic ganglions in connexion with the splenic artery become enlarged, coalesce, and in no long time form masses of considerable size, which probably execute to a certain extent the functions of the extirpated organ. In ten months, in ducks and hens, a glandular mass existed, equal in size to the original spleen. This, he thinks, will account in part for the trifling disturbance of function resulting from extirpation of the organ.

It is impracticable, then, to arrive at any exclusive theory regarding the functions of this anomalous organ. Whilst it is probably inservient to lymphosis and to the purposes assigned it by Tiedemann and Gmelin; its office must be of a supplementary or vicarious nature; for it is manifestly not essential to life. It doubtless serves also as a diverticulum;—the blood speedily passing, after it has been extirpated, into other channels;—a view, which, as elsewhere remarked,[2] is somewhat confirmed by the splenic enlargements consequent on repeated attacks of intermittent,—the blood, which has receded from the surface, accumulating perhaps in this organ. It must be admitted, however, that our knowledge of the function is of a singularly negative and unsatisfactory character; and this is strikingly exemplified by the suggestion of Dr. Paley[3]—who was certainly not predisposed to arrive at such a conclusion—that the spleen "may be merely a stuffing, a soft cushion to fill up a vacuum or hollow, which, unless occupied, would leave the package loose and unsteady."

CHAPTER VII.

CALORIFICATION.

The function we have now to consider is one of the most important to organized existence, and one of the most curious in its causes and results. It has, consequently, been an object of interesting examination with the physiologist, both in animals and plants; and as it has been presumed to be greatly owing to respiration, it has been a favourite topic with the chemist also. Most of the hypotheses, devised for its explanation, have, indeed, been of a chemical character; and hence it will be advisable to premise a few observations regarding the physical relations of *caloric* or the *matter of heat*,—an imponderable body, according to common belief, which is generally distributed throughout

[1] London Med. Times, Mar. 25, 1845, p. 550.
[2] Practice of Medicine, ii. 103, 3d edit., Philad., 1848.
[3] Natural Theology, c. 11.

nature. It is this that constitutes the *temperature* of bodies,—by which is meant, the sensation of heat or cold we experience when they are touched by us; or the height at which the mercury is raised or depressed by them, in the instrument called the *thermometer;*—the elevation of the mercury being caused by the caloric entering between its particles, and thus adding to its bulk; and the depression produced by the abstraction of caloric.

Caloric exists in bodies in two states;—in the *free*, *uncombined* or *sensible;* and in the *latent* or *combined.* In the latter case, it is intimately united with the other elementary constituents of bodies, and is neither indicated by the feelings nor thermometer. It has, consequently, no agency in the temperature of bodies; but, by its proportion to the force of cohesion, it determines their condition;—whether solid, liquid or gaseous. In the former case, caloric is simply interposed between the molecules; and is incessantly disengaged, or abstracted from surrounding bodies; and, by impressing the surface of the body or by acting upon the thermometer, indicates to us their temperature. Equal weights of the same body, at the same temperature, contain the same quantities of caloric; but equal weights of different bodies at the same temperature have by no means the same. The quantity, which one body contains, compared with another, is called its *specific caloric* or *specific heat;* and the power or property, which enables bodies to retain different quantities of caloric, is called *capacity for caloric.* If a pound of water heated to 156° be mixed with a pound of quicksilver at 40°, the resulting temperature is 152°,—instead of 98°, the exact mean. The water, consequently, must have lost four degrees of temperature, and the quicksilver gained one hundred and twelve; from which we deduce, that the quantity of caloric, capable of raising one pound of mercury from 40° to 152° is the same as that required to raise one pound of water from 152° to 156°; in other words, that the same quantity of heat, which raises the temperature of a pound of water four degrees, raises the same weight of mercury one hundred and twelve degrees. Accordingly, it is said, that the *capacity* of water for heat is to that of mercury, as 28 to 1; and that the *specific heat* is twenty-eight times greater.

All bodies are capable of giving and taking free caloric; and consequently, all have a temperature. If the quantity given off be great, the temperature of the body is elevated. If it takes heat from the thermometer, it is cooler than the instrument. In inorganic bodies, the disengagement of caloric is induced by various causes,—such as electricity, friction, percussion, compression, the change of condition from a fluid to a solid state; and by chemical changes, giving rise to new compounds, so that the caloric, which was previously latent, becomes free. If, for example, two substances, each containing a certain amount of specific heat, unite, so as to form a compound whose specific heat is less, a portion of caloric must be set free, and this will be indicated by a rise in the temperature. It is this principle, which is chiefly concerned in some of the theories of calorification.

The subject of the equilibrium and conduction of caloric is elsewhere treated of, under the sense of Touch; where other topics are discussed, that bear more or less upon the present inquiry. It is there stated, that inorganic bodies speedily attain the same temperature, either by radiation or conduction; so that the different objects in an apartment exhibit the same degree of heat by the thermometer; but the temperature of animals being the result of a vital operation, they retain the degree of heat peculiar to them with but little modification from external temperature. There is a difference, however, in this respect, sufficient to cause the partition of animals into two great divisions—the *warm-blooded* and *cold-blooded;* the former comprising those whose temperature is high, and but little influenced by that of external objects;—the latter those whose temperature is greatly modified by external influences. The range of the temperature of the warm-blooded—amongst which are all the higher animals—is limited; but of the cold-blooded extensive. The following table exhibits the temperature of various animals in round numbers;—that of man being estimated at 98° or 100°, when taken under the tongue. Dr. John Davy[1] makes the mean of numerous observations, thus taken, 100°. The temperature in the axilla is something less. M. Gavarret,[2] however, estimates it from about 98° to 100°. MM. Prevost and Dumas,[3] and Dr. Brown-Séquard[4] would place the normal temperature of man higher than this,—at not less than 102°. In the axilla, M. Edwards[5] found it vary, in twenty adults, from 96° to 99° Fahrenheit, the mean being 97·5°. It would appear, however, to differ at different periods of the day. Hallmann, from his own observations and those of Gierse,[6] found that the temperature of healthy individuals under the tongue was on the average 37° Cent., or 98·66° Fahr.; late in the morning and evening from 36·7° to 36·8° Cent.,—from 98·06° to 98·24° Fahr.; in the forenoon, at 37·3° Cent.—99·14° Fahr.; and in the afternoon, at 37·5° Cent.—99·5° Fahr.

ANIMALS.	OBSERVERS.	TEMPERATURE.
Active young horse, four years old,	Metcalfe.[7]	104°
Arctic fox,	Capt. Lyon.[8]	107
Arctic wolf,	Do.	105
Squirrel,	Pallas.[9]	
Hare,	Do.	104
Whale,	Scoresby.[10]	
Arctomys citillus, zizil,—in summer,	Pallas.	103
Do. when torpid,	Pallas.	80 to 84
Goat,	Prévost and Dumas.[11]	103
She goat, three months old,	Metcalfe.	107
Mother of the same, old, and in poor condition,	Do.	104
Bat, in summer,	Prévost and Dumas.	102
Musk,	Do.	

[1] Researches, Physiological and Anatomical, Amer. edit., p. 290, Philad., 1840.
[2] De la Chaleur Produite par les Etres Vivants, p. 100, Paris, 1855.
[3] Annales de Chimie et de Physique, 2e Série, xxiii. 64.
[4] Med. Examiner, Sept., 1852, p. 554.
[5] De l'Influence des Agens Physiques, &c., Paris, 1824; or Hodgkin's and Fisher's translation, Lond., 1832.
[6] Henle, Handbuch der rationellen Pathologie, 1 Band. S. 301, Braunschweig, 1846.
[7] Caloric, its Mechanical, Chemical, and Vital Agencies in the Phenomena of Nature, ii. 567, Lond., 1843.
[8] Parry's Second Voyage to the Arctic Regions.
[9] Nov. Species Quadruped. de Glirium Ordine, Erlang., 1774.
[10] An Account of the Arctic Regions, Edinb., 1820.
[11] Bibliothèque Univers., xvii. 294.

ANIMALS.	OBSERVERS.	TEMPERATURE.
Marmota bobac,—Bobac,	Prévost and Dumas.	101 or 102°
House mouse,	Do.	101
Arctomys marmota, marmot—in summer,	Do.	101 or 102
Do. when torpid,	Do.	43
Rabbit,	Delaroche.	100 to 104
Tame young rabbit, two months old,	Metcalfe.	108
Polar bear,	Capt. Lyon.	100
Dog,	Martine.[1]	100 to 103
Cat,	Do.	
Swine,	Do.	
Sheep,	Do.	
Ox,	Do.	
A fine active kitten, two months old,	Metcalfe.	105·5
A vigorous cat, nearly full grown,	Do.	104
Mother of the kitten, three years old,	Do.	103·5
A very old cat, said to be in its 19th year,	Do.	102
An active cur dog, three months old,	Do.	106
Guinea-pig,	Delaroche.	100 to 102
Arctomys glis,	Pallas.	99
Shrew,	Do.	98
Young wolf,	Do.	96
Fringilla arctica, Arctic finch,	Braun.[2]	111
Rubecola, redbreast,	Pallas.	
Fringilla linaria, lesser red poll,	Do.	110 or 111
Falco palumbarius, goshawk,	Do.	110
Caprimulgus Europæus, European goat-sucker,	Do.	
Emberiza nivalis, snow-bunting,	Do.	109 to 110
Falco lanarius, lanner,	Do.	109
Fringilla carduelis, goldfinch,	Do.	
Corvus corax, raven,	Despretz.[3]	
Turdus, thrush, (of Ceylon,)	J. Davy.[4]	
Tetrao perdrix, partridge,	Pallas.	
Anas clypeata, shoveler,	Do.	108
Tringa pugnax, ruffe,	Do.	
Scolopax limosa, lesser godwit,	Do.	
Tetrao tetrix, grouse,	Do.	
Fringilla brumalis, winterfinch,	Do.	
Loxia pyrrhula,	Do.	
Falco nisus, sparrowhawk,	Do.	
Vultur barbatus,	Do.	
Anser pulchricollis,	Do.	107
Colymbus auritus, dusky grebe,	Do.	
Tringa vanellus, lapwing, (wounded,)	Do.	
Tetrao lagopus, ptarmigan,	Do.	
Fringilla domestica, house-sparrow,	Do.	107 to 111
Strix passerina, little owl,	Do.	106
Hæmatopus estralagus, sea-pie,	Do.	
Anas penelope, widgeon,	Do.	
Anas strepera, gadwall,	Do.	
Pelecanus carbo,	Do.	
Falco ossifragus, sea-eagle,	Do.	105
Fulica atra, coot,	Do.	
Anas acuta, pintail-duck,	Do.	
Falco milvus, kite, (wounded,)	Do.	104
Merops apiaster, bee-eater,	Do.	
Goose,	Martine.	103 to 107
Hen,	Do.	
Dove,	Do.	
Duck,	Do.	

[1] Med. and Philos. Essays, Lond., 1740; and De Similibus Animalibus et Animal. Calore, &c., Lond., 1740.

[2] Nov. Comment. Acad. Petropol., xiii. 419.

[3] Annales de Chimie, xxvi. 337, Amst., 1824.

[4] Edinb. Philos. Journal, Jan., 1826.

ANIMALS.	OBSERVERS.	TEMPERATURE.
Ardea stellaris,	Pallas.	103°
Falco albicollis,	Do.	
Picus major,	Do.	
Cossus ligniperda,	Shultze.	89 to 91
Shark,	J. Davy.	83
Torpedo Marmorata,	Rudolphi.[1]	74

It will be observed, that according to this table the inhabitants of the Arctic regions—whether belonging to the class of mammalia or birds—are among those whose temperature is highest. That of the Arctic fox is probably higher than given in the table, as it was taken after death, when the temperature of the air was as low as —14° of Fahrenheit, and when loss of heat may be supposed to have occurred rapidly.

It is, of course, impracticable to mark the temperature of the smaller insects, but we can arrive at an approximation in those that congregate in masses, as the bee and the ant; for it is difficult to suppose with Miraldi, that the augmented temperature is dependent upon the motion and friction of the wings and bodies of the busy multitudes. Juch[2] found, when the temperature of the atmosphere was —18° of Fahrenheit, that of a hive of bees 44°: in an ant-hill, the thermometer stood at 68° or 70°, when the temperature of the air was 55°; and at 75°, when that of the air was 66°; and Hausmann[3] and Rengger[4] saw the thermometer rise when put into narrow glasses in which they had placed scarabæi and other insects.[5] Berthold detected the elevation of heat only when several insects were collected together, never in one isolated from the rest. This, according to Mr. Newport,[6] must have arisen from his having ascertained the temperature only whilst the insect was in a state of repose; for Mr. Newport found, that although during such a state, the temperature of the insect was very nearly or exactly that of the surrounding medium; yet when it was excited or disturbed, or in a state of great activity from any cause, the thermometer rose, in some instances, even to 20° Fahr. above the temperature of the atmosphere,—for instance, to 91°, when the heat of the air was 71°.[7]

The power of preserving their temperature within certain limits is not, however, possessed exclusively by animals. The heat of a tree, examined by Mr. Hunter,[8] was found to be always several degrees higher than that of the atmosphere, when the latter was below 56° of Fahr.; but it was always several degrees below it when the weather was warmer. Some plants develope a great degree of heat during the period of blooming. This was first noticed by De Lamarck[9] in *Arum Italicum*. In *Arum cordifolium*, of the Isle of Bourbon, M. Hubert

[1] Grundriss der Physiol., &c., Band. i. 166.
[2] Ideen zu einer Zoochemie, i. 90.
[3] De Animal. Exsanguium Respiratione, p. 65.
[4] Physiologische Untersuchung. über die Insecten, p. 40, Tübing., 1817.
[5] Tiedemann, op. citat., p. 511.
[6] Philos. Transact., for 1837, part ii. p. 259.
[7] See a table of the recorded observations of J. Davy, Berthold, Becquerel, Newport, Dutrochet, Hunter and Valentin, on the excess of temperature of the articulata and annelida over that of the circumambient air, in Gavarret, De la Chaleur produite par les Etres Vivants, p. 130, Paris, 1855.
[8] Philos. Transact., 1775 and 1778.
[9] Encyclop. Méthod., iii. 9.

found, when the temperature of the air was 80°, that of the spathe or sheath was as high as 134°; and M. Bory de St. Vincent[1] observed a similar elevation, although to a less degree, in *Arum esculentum*, *esculent arum* or *Indian kale*. The most exact and elaborate investigations appear to have been made by MM. Vrolik and De Vriese.[2] According to them, the temperature has a regular periodicity within the twenty-four hours, and attains its maximum in the afternoon between the hours of two and five. The difference between the temperature of the atmosphere and that of the root is sometimes as much as from 20° to 30° of Réaumur. According to M. de Saussure, the root of an arum maculatum converted thirty times its volume of oxygen into carbonic acid in twenty-four hours. In all cases, the absolute temperature appeared to depend on the intensity of the vital processes, and was higher in proportion to the vigour of the vegetation in plants, or to the absorption of the sap and the activity of its chemical processes;[3] and accurate and repeated observation seems to justify the conclusion of M. Gavarret,[4] that at all periods of the developement of a plant, whether we study it during germination or vegetation, in its green parts or its reproductive organs, it will be found—as in the animal—that the physico-chemical phenomena of nutrition are the true sources of the heat which it produces.

The temperature of the animal body is so far influenced by external heat as to rise or fall with it; but the range, as already remarked, is limited in the warm-blooded animal,—more extensive in the cold-blooded. Dr. Currie found the temperature of a man plunged into sea-water at 44° sink, in the course of a minute and a half after immersion, from 98° to 87°: in other experiments, it descended as low as 85°, and even to 83°.[5] It was always found, however, that, in a few minutes, the heat approached its previous elevation; and in no instance could it be depressed lower than 83°, or 15° below the temperature at the commencement of the operation. Similar experiments have been performed on other warm-blooded animals. Mr. Hunter found the temperature of a common mouse to be 99°, that of the atmosphere being 60°: when the same animal was exposed for an hour, to an atmosphere of 15°, its heat had sunk to 83°;[6] but the depression could be carried no farther. He found, also, that a dormouse,—whose heat in an atmosphere at 64°, was 81½°—when put into air, at 20°, had its temperature raised in the course of half an hour to 93°; an hour after, the air being at 30°, it was still 93°; another hour after, the air being at 19°, the heat of the pelvis was as low as 83°,—an experiment which strongly proves the great counteracting influence exerted, when animals are exposed to an unusually low temperature. In this experiment the dormouse had maintained its temperature about 70° higher than that of the surrounding medium, and for the space of two hours and a half. In the hibernating torpid quadruped the reduction of temperature, during their torpidity, is considerable. Jenner[7] found the temperature

[1] Voyage dans les Quatre Principales Iles des Mers d'Afrique, ii. 66.
[2] Annales de Chimie et de Physique, xxi. 279.
[3] Schleiden, Principles of Scientific Botany, by Dr. Lankester, p. 541, London, 1849.
[4] Op. cit., p. 544.
[5] Philos. Transact. for 1792, p. 199.
[6] Ibid., 1778, p. 21.
[7] Hunter, On the Animal Economy, with Professor Owen's notes, p. 165, Philad., 1840.

of a hedgehog, in the cavity of the abdomen, towards the pelvis, to be 95°, and that of the diaphragm 97° of Fahrenheit, in summer, when the thermometer in the shade stood at 78°; whilst in winter, the temperature of the air being 44°, and the animal torpid, the heat in the pelvis was 45°, and that of the diaphragm 48½°. When the temperature of the atmosphere was 26°, the heat of the animal in the cavity of the abdomen, where an incision was made, was reduced as low as 30°; but—what singularly exhibits the power possessed by the system of regulating its temperature—when the same animal was exposed to a cold atmosphere of 26° for two days, the heat, in the rectum, marked 93°, or 67° above that of the atmosphere. At this time, however, it was lively and active, and the bed on which it lay felt warm. In the cold-blooded animal, we have equal evidence of the generation of heat. Hunter found the heat of a viper, placed in a vessel at 10°, reduced, in ten minutes, to 37°; in the next ten minutes, the temperature of the vessel being 13°, it fell to 35°; and in the next ten, that of the vessel being 20°, to 31°.[1] In frogs, he was able to lower the temperature to 31°; but beyond this point it was not possible to depress it, without destroying the animal.

In the Arctic regions, animal temperature appears to be steadily maintained notwithstanding the intense cold that prevails; and we have already seen, that the animals of those hyperborean latitudes possess a more elevated temperature than those of more genial climes. In the earlier enterprising voyages, undertaken by the British government for the discovery of a northwest passage, the crews of the ships were frequently exposed to the temperature of —40° or —50° of Fahrenheit's scale; and the same thing happened during the disastrous campaign of Russia in 1812, in which so many of the French army perished from cold. The lowest temperature noticed by Captain Parry[2] was —55° of Fahrenheit. Captain Franklin,[3] on the northern part of this continent, observed the thermometer on one occasion—Feb. 7, 1827,—as low as —58° of Fahrenheit. Von Wrangel[4] states that, in January, on the north coast of Siberia, it reaches —59° of Fahrenheit. Mr. Rae,[5] at Repulse Bay, early in January, marked the thermometer at —47°. In the Arctic expedition of 1851, the lowest temperature was noted on the 22d of February, when the ship's thermometer gave —46°; Dr. Kane's "off-ship spirit" —52°; and his self-registering thermometers, placed on a hummock away from the vessels, gave —53° as the mean of two instruments.[6] Mr. Saunders, commander of the North Star, records —63½° as the lowest tempera-

[1] Op. citat.

[2] Journal of a Voyage for the Discovery of a Northwest Passage, American edition, p. 130, Philadelphia, 1821.

[3] Narrative of a Second Expedition to the Shores of the Polar Sea, &c., American edition, p. 245, Philadelphia, 1835.

[4] Reise des kaiserlich Russischen Flotten Lieutenants Ferdinand Von Wrangel, längs der Nordküste von Siberien, u. s. w., Berlin, 1839, translated in Harper's Family Library.

[5] Narrative of an Expedition to the Shores of the Arctic Sea in 1846 and 1847, Lond., 1850.

[6] The U. S. Grinnel Expedition in search of Sir John Franklin, By Elisha Kent Kane, M. D., U. S. N., p. 310, New York, 1853.

ture observed in Wolstenholme Sound, in the winter of 1850;[1] and Sir John Richardson[2] noted it at Fort Confidence in 66° 54′ N. L., and 118° 49′ W. L., at —65° in the winter of 1848-9. The extremes of cold experienced by Captain McClure and his party at Mercy Bay in Jan. and Feb., 1855, were —62° and —65°. In the Arctic expedition of 1853-4, under the command of Dr. Kane, the range of eleven spirit thermometers, selected as standards, varied from —60° to —75°. The mean annual temperature was 5°.2:—the lowest ever registered. Captain Back,[3] in his expedition to the Arctic regions of this continent, on the 17th of January, 1834, noticed the thermometer at —70° of Fahrenheit. Mr. Erman[4] states, that at Yakutsk it was at —72·5 of Fahrenheit; and Sir George Simpson[5] affirms, that it has fallen in Siberia to —83° or 115° below the freezing point, which—if the thermometers could be depended upon—may be regarded as the greatest depression observed in any climate. The great variation, however, even in spirit instruments selected as standards, at these very depressed temperatures as observed by Dr. Kane, throws doubts as to the actual temperature unless taken by different thermometers.

During the second voyage of Captain Parry,[6] the following temperatures of animals, immediately after death, were taken principally by Captain Lyon.

		Temperature of the Animal.	Temperature of the Atmosphere.
1821.			
Nov. 15.	An Arctic fox	$106\frac{3}{4}$°	— 14°
Dec. 3.	Do.	$101\frac{1}{2}$	— 5
	Do.	100	— 3
11.	Do.	$101\frac{1}{4}$	— 21
15.	Do.	$99\frac{3}{4}$	— 15
17.	Do.	98	— 10
19.	Do.	$99\frac{3}{4}$	— 14
1822.			
Jan. 3.	Do.	$104\frac{1}{2}$	— 23
9.	A white hare	101	— 21
10.	An Arctic fox	100	— 15
17.	Do.	106	— 32
24.	Do.	103	— 27
	Do.	103	— 27
	Do.	102	— 25
27.	Do.	101	— 32
Feb. 2.	A wolf	105	— 27

These animals must, therefore, have to maintain a temperature at least 100° higher than that of the atmosphere throughout the whole of winter; and it would seem as if the counteracting energy becomes proportionately greater as the temperature is more depressed. It is,

[1] Journal of a Voyage in Baffin's Bay and Barrow's Straits in the years 1850—1851, performed by H. M. Ships Lady Franklin and Sophia, under the command of Mr. William Penny, &c. &c., By Peter C. Sutherland, M. D., &c., i. 285, London, 1852.

[2] Arctic Searching Expedition: a Journal of a Boat's Voyage through Rupert's Land and the Arctic Sea, in search of the discovery ships under command of Sir John Franklin, ii. 102, London, 1851.

[3] Narrative of the Arctic Land Expedition to the mouth of the Great Fish River, &c., in the years 1833, 1834, and 1835, London, 1836.

[4] Travels in Siberia, translated from the German, by W. D. Cooley, ii. 369, London, 1848.

[5] An Overland Journey round the World, Amer. edit., part ii. p. 134, Philad., 1847.

[6] Op. citat., p. 157.

however, a part of their nature to be constantly eliciting this unusual quantity of caloric, and therefore they do not suffer. Where animals, not so accustomed, are placed in an unusually cold medium, the efforts of the system rapidly exhaust the nervous energy; and when this is so far depressed as to interfere materially with the function of calorification, the temperature sinks, and the sufferer dies lethargic—or as if struck with apoplexy. The ship Endeavour, being on the coast of Terra del Fuego, on the 21st of December, 1769, Messrs. Banks, Solander, and others were desirous of making a botanical excursion on the hills on the coast, which did not appear to be far distant. The party, consisting of eleven persons, were overtaken by night, during extreme cold. Dr. Solander, who had crossed the mountains which divide Sweden from Norway, knowing the almost irresistible desire for sleep produced by exposure to great cold, more especially when united with fatigue, enjoined his companions to keep moving, whatever pains it might cost them, and whatever might be the relief promised by an indulgence in rest. "Whoever sits down," said he, "will sleep, and whoever sleeps will wake no more." Thus admonished, they set forward, but whilst still upon the bare rock, and before they had got among the bushes, the cold suddenly became so severe as to produce the effects that had been dreaded. Dr. Solander himself was the first who found the desire irresistible, and insisted on being suffered to lie down. Mr. Banks (afterwards Sir Joseph) entreated and remonstrated in vain. The doctor lay down upon the ground, although it was covered with snow; and it was with the greatest difficulty that his friend could keep him from sleeping. Richmond, one of the black servants, began to linger and to suffer from the cold, in the same manner as Dr. Solander. Mr. Banks, therefore, sent five of the company forward to get a fire ready at the first convenient place they came to; and himself, with four others, remained with the Doctor and Richmond, whom, partly by persuasion and partly by force, they carried forward; but when they had got through the birch and swamp, they both declared they could go no farther. Mr. Banks had again recourse to entreaty and expostulation, but without effect. When Richmond was told, that if he did not go on, he would, in a short time, be frozen to death, he answered, that he desired nothing but to lie down and die. Dr. Solander was not so obstinate, but was willing to go on, if they would first allow him to take some sleep, although he had before observed, that to sleep was to perish. Mr. Banks and the rest of the party found it impossible to carry them, and they were consequently suffered to sit down, being partly supported by the bushes, and, in a few minutes, they fell into a profound sleep. Soon after, some of the people, who had been sent forward, returned with the welcome intelligence, that a fire had been kindled about a quarter of a mile farther on the way. Mr. Banks then endeavoured to rouse Dr. Solander, and happily succeeded; but, although he had not slept five minutes, he had almost lost the use of his limbs, and the soft parts were so shrunk, that his shoes fell from his feet. He consented to go forward with such assistance as could be given him; but no attempts to relieve Richmond were successful. He, with another black left with him, died. Several others began to lose their sensibility, having been exposed to the cold near an hour and a half, but the fire recovered them.

The preceding history is interesting in another point of view besides the one for which it was more especially narrated. Both the individuals, who perished, were blacks; and it has been a common observation, that they bear exposure to great heat with more impunity, and suffer more from intense cold, than the white variety of the species. As regards inorganic bodies, it has been satisfactorily shown, that the phenomena of the radiation of caloric are connected with the nature of the radiating surface; and that those surfaces, which radiate most, possess, in the highest degree, the absorbing power; in other words, bodies that have their temperatures most readily raised by radiant heat are those that are most easily cooled by their own radiation. In the experiments of Professor Leslie[1] it was found, that a clean metallic surface produced an effect upon the thermometer equal to 12; but when covered with a thin coat of glue its radiating power was so far increased as to produce one equal to 80; and, on covering it with lampblack, it became equal to 100. We can thus understand why, in the negro, there should be a greater expense of caloric than in the white, owing to the greater radiation; not because as much caloric may not have been elicited as in the white. In the same manner we can comprehend, that, owing to the greater absorbing power of his skin, he may suffer less from excessive heat. To ascertain, whether such be the fact, the following experiments were instituted by Sir Everard Home.[2] He exposed the back of his hand to the sun at twelve o'clock, with a thermometer attached to it, another being placed upon a table with the same exposure. The temperature, indicated by that on his hand, was 90°; by the other, 102°. In forty-five minutes, blisters arose, and coagulable lymph was thrown out. The pain was very severe. In a second experiment, he exposed his face, eyelids, and the back of his hand to water heated to 120°; in a few minutes they became painful; and, when the heat was farther increased, he was unable to bear it; but no blisters were produced. In a third experiment, he exposed the backs of both hands, with a thermometer upon each, to the sun's rays. The one hand was uncovered; the other had a covering of black cloth, under which the ball of the thermometer was placed. After ten minutes, the degree of heat of each thermometer was marked, and the appearance of the skin examined. This was repeated at three different times. The first time, the thermometer under the cloth stood at 91°; the other at 85°; the second time, they indicated respectively 94° and 91°; and the third time, 106° and 98°. In every one of these trials, the skin that was uncovered was scorched; whilst the other had not suffered in the slightest degree. From all his experiments, Sir Everard concludes, that the power of the sun's rays to scorch the skin of animals is destroyed, when applied to a black surface; although the absolute heat, in consequence of the absorption of the rays, is greater.

When cold is applied to particular parts of the body, their heat

[1] On Heat, Lond., 1788; and Dr. Stark, in Philosoph. Transact., part ii. for 1833.
[2] Lect. on Comp. Anat., iii. 217, London, 1823.

sinks lower than the minimum of depressed temperature. Although Mr. Hunter was unable to heat the urethra one degree above the maximum of elevated temperature of the body, he succeeded in cooling it 29° lower than the minimum of depressed temperature, or to 58°. He cooled down the ears of rabbits until they froze; and when thawed they recovered their natural heat and circulation. The same experiment was performed on the comb and wattles of a cock. Resuscitation was, however, in no instance practicable where the whole body had been frozen.[1] The same distinguished observer found, that the power of generating heat, when exposed to a cooling influence, was possessed even by the egg. One, that had been frozen and thawed, was put into a cold mixture along with one newly laid. The latter was seven minutes and a half longer in freezing than the former. In another experiment, a fresh-laid egg, and one that had been frozen and thawed, were put into a cold mixture at 15°; the thawed one soon rose to 32°, and began to swell and congeal; the fresh one sank to 29½°, and in twenty-five minutes after the dead one, rose to 32°, and began to swell and freeze. All these facts prove, that when the living body is exposed to a lower temperature than usual, a counteracting power of calorification exists; but that, in the human species, such exposure to cold is incapable of depressing the temperature of the system lower than about 15° beneath the natural standard. In fish, the vital principle can survive the action even of frost. Captain Franklin found, that those which they caught in Winter Lake, froze as they were taken out of the net; but if, in this completely frozen condition, they were thawed before the fire, they recovered their animation. This was especially the case with a carp, which recovered so far as to leap about with some vigour after it had been frozen for thirty-six hours.

On the other hand, when the living body is exposed to a temperature greatly above the natural standard, an action of refrigeration is exerted; so that the animal heat cannot rise beyond a certain number of degrees; —to a much smaller extent in fact than it is capable of being depressed by the opposite influence. Boerhaave[2] maintained the strange opinion, that no warm-blooded animal could exist in a temperature higher than that of its own body. In some parts of Virginia, there are days in every summer, in which the thermometer reaches 98° of Fahrenheit; and in other parts of this country it is occasionally much higher. The meteorological registers show it to be, at times, at 108° at Council Bluffs, in Missouri; at 104° in New York; and at 100° in Michigan;[3] whilst in most of the states, in some days of summer, it reaches 96° or 98°. At Sierra Leone, Messrs. Watt and Winterbottom[4] saw it frequently at 100°, and even as high as 102° and 103°, at some distance from the coast. Adanson observed it at Senegal as high as 108½°. Sir John

[1] Sir E. Home's Lect., &c., iii. 438.

[2] "Observatio docet nullum animal quod pulmones habet posse in aere vivere, cujus eadem est temperies cum suo sanguine." Element. Chemiæ, i. 275, Lug. Bat., 1732.

[3] Meteorological Register, for the years 1822, 1823, 1824, and 1825, from observations made by the surgeons at the military posts of the United States. See, also, a similar register for the years 1826, 1827, 1828, 1829, and 1830, Philad., 1840; and another from 1843 to 1854, inclusive, Washington, 1855.

[4] Account of the Native Africans, vol. i. pp. 32 and 33.

Barrow,[1] at the village of Graaf Reynet, in South Africa, noted it on the 24th of November, at 108° in the shade and open air. Brydone affirms, that when the sirocco blows in Sicily the heat rises to 112°.[2] Dr. Chalmers observed a heat of 115°[3] in South Carolina; Humboldt[4] of 110° to 115° in the Llanos or Plains near the Orinoco; and Captain Tuckey asserts, that on the Red Sea he never saw the thermometer at midnight under 94°; at sunrise under 104°; or at midday under 112°. In British India it has been seen as high as 130°.[5]

As long ago as 1758, Governor Ellis[6] of Georgia had noticed how little the heat of the body is influenced by that of the external atmosphere. "I have frequently," he remarks, "walked an hundred yards under an umbrella with a thermometer suspended from it by a thread, to the height of my nostrils, when the mercury has rose to 105°, which is prodigious. At the same time I have confined this instrument close to the hottest part of my body, and have been astonished to observe, that it has subsided several degrees. Indeed I could never raise the mercury above 97° with the heat of my body." Two years after the date of this communication, the power of resisting a much higher atmospheric temperature was discovered by accident. MM. Duhamel and Tillet,[7] in some experiments for destroying an insect, that infested the grain of the neighbourhood in Angoumois,—having occasion to use a large public oven, on the same day in which bread had been baked in it,—were desirous of ascertaining its temperature. This they endeavoured to accomplish by introducing a thermometer into the oven at the end of a shovel. On being withdrawn, the thermometer indicated a degree of heat considerably above that of boiling water; but M. Tillet, feeling satisfied, that the thermometer had fallen several degrees in approaching the mouth of the oven, and seeming to be at a loss how to rectify the error, a girl,—one of the servants of the baker, and an attendant on the oven,—offered to enter and mark with a pencil the height at which the thermometer stood within. She smiled at M. Tillet's hesitation in accepting her proposition; entered the oven, and noted the temperature to be 260° of Fahrenheit. M. Tillet, anxious for her safety, called upon her to come out; but she assured him she felt no inconvenience, and remained ten minutes longer, when the thermometer had risen to 280° and upwards. She then came out of the oven, with her face considerably flushed, but her respiration by no means quick or laborious.

These facts excited considerable interest; but no farther experiments appear to have been instituted, until, in the year 1774, Dr. Geo. Fordyce, and Sir Charles Blagden[8] made their celebrated trials with heated air. The rooms, in which these were made, were heated by flues in the floor. Having taken off his coat, waistcoat, and shirt, and being

[1] Auto-biographical Memoir, p. 193, London, 1847.
[2] Lawrence's Lectures on Comparative Anatomy, Physiology, &c., p. 306, London, 1819.
[3] Account of the Weather and Diseases of South Carolina, London, 1776.
[4] Tableau Physique des Regions Équatoriales.
[5] Prof. Jameson, British India, Amer. edit., iii. 170, New York, 1832.
[6] Philosophical Transactions, 1758, p. 755.
[7] Mémoir. de l'Académie des Sciences, p. 186, Paris, 1762.
[8] Philosophical Transactions for 1775, p. 111.

provided with wooden shoes tied on with list, Dr. Fordyce went into one of the rooms, as soon as the thermometer indicated a degree of heat above that of boiling water. The first impression of the heated air upon his body was exceedingly disagreeable; but in a few minutes all uneasiness was removed by copious perspiration. At the end of twelve minutes he left the room very much fatigued; but not otherwise disordered. The thermometer had risen to 220°. In other experiments, it was found, that a heat even of 260° could be borne with tolerable ease. At this temperature, every piece of metal was intolerably hot; small quantities of water, in metallic vessels, quickly boiled; and streams of moisture poured down over the whole surface of his body. That this was merely the vapour of the room, condensed by the cooler skin, was proved by the fact, that when a Florence flask, filled with water of the same temperature as the body, was placed in the room, the vapour condensed in like manner upon its surface, and ran down in streams. Whenever the thermometer was breathed upon, the mercury sank several degrees. Every expiration—especially if made with any degree of violence—communicated a pleasant impression of coolness to the nostrils, scorched immediately before by the hot air rushing against them when they inspired. In the same manner, their comparatively cool breath cooled the fingers, whenever it reached them. "To prove," says Sir Charles Blagden, "that there was no fallacy in the degree of heat shown by the thermometer, but that the air which we breathed was capable of producing all the well-known effects of such an heat on inanimate matter, we put some eggs and beef-steak upon a tin frame, placed near the standard thermometer, and farther distant from the cockle than from the wall of the room. In about twenty minutes the eggs were taken out roasted quite hard; and in forty-seven minutes, the steak was not only dressed, but almost dry. Another beef-steak was rather overdone in thirty-three minutes. In the evening, when the heat was still greater, we laid a third beef-steak in the same place; and as it had now been observed, that the effect of the heated air was much increased by putting it in motion, we blew upon the steak with a pair of bellows, which produced a visible change on its surface, and seemed to hasten the dressing; the greatest part of it was found pretty well done in thirteen minutes." In all these experiments, and others of a like kind were made in the following year, by Dr. Dobson,[1] of Liverpool, the heat of the body, in air of a high temperature, speedily reached 100°; but exposure to 212° and more did not carry it higher.

These results are not exactly in accordance with those of MM. Berger and Delaroche,[2] from experiments performed in 1806. Having exposed themselves, for some time, to a stove,—the temperature of which was 39° of Réaumur or 120° of Fahrenheit—their temperature was raised 3° of Réaumur or $6\frac{3}{4}$° of Fahrenheit; and M. Delaroche found, that his rose to 4° of Réaumur or 9° of Fahrenheit, when he had remained sixteen minutes in a stove heated to 176° of Fahrenheit.

[1] Philosophical Transactions for 1775, p. 463.

[2] Expér. sur les Effets qu'une forte Chaleur produit sur l'Économie, Paris, 1805; and Journal de Physique, lxiii. 207, lxxi. 289, and lxxvii. 1.

According to Sir David Brewster,[1]—the distinguished sculptor, Chantry, exposed himself to a temperature yet higher. The furnace which he employed for drying his moulds was about 14 feet long, 12 high, and 12 broad. When raised to its highest temperature, with the doors closed, the thermometer stood at 350°, and the iron floor was *red-hot.* The workmen often entered it at a temperature of 340°, walking over the floor with wooden clogs, which were, of course, charred on the surface. On one occasion, Sir Francis, accompanied by five or six of his friends, entered the furnace, and after remaining two minutes, brought out a thermometer, which stood at 320°. Some of the party experienced sharp pains in the tips of their ears, and in the septum of the nose, whilst others felt a pain in the eyes. In certain experiments of Chabert, who exhibited his powers as a "Fire King," in this country as well as in Europe, he is said to have entered an oven with impunity, the heat of which was from 400° to 600° of Fahrenheit.

Experiments have shown, that the same power of resisting excessive heat is possessed by animals. Drs. Fordyce and Blagden shut up a dog, for half an hour, in a room, the temperature of which was between 220° and 236°; at the end of this time a thermometer was applied between the thigh and flank of the animal; and in about a minute the mercury sank to 110°; but the real heat of the body was certainly less than this, as the ball of the thermometer could not be kept a sufficient time in proper contact; and the hair, which felt sensibly hotter than the bare skin, could not be prevented from touching the instrument. The temperature of this animal, in the natural state, is 101°.

We find in organized bodies astonishing cases of adaptation to the medium in which they live. Sonnerat saw, in India, Vitex agnus castus flourishing near a spring, whose temperature was 144°; and Foster found it at the foot of a volcano in the Island of Tanna, the temperature of the ground being 176°. Adanson affirms, that different plants vegetate and preserve their verdure in Senegal, although their roots are plunged in sand at a temperature at times as high as 142°; and M. Desfontaines found several plants surrounding the springs at Bonne in Barbary, the heat of which was as high as 171°.[2]

Although man is capable of breathing with impunity air heated to above the boiling point of water, we have seen, that he cannot bear the contact of water much below that temperature. Yet we find certain of the lower animals—as fish—living in water at a temperature which would be sufficient to boil them if dead. In the thermal springs of Bahia, in Brazil, many small fishes are seen swimming in a rivulet, which raises the thermometer to 88°, when the temperature of the air is only 77½°. Sonnerat found fishes existing in a hot spring at the Manillas, at 158° Fahr.; and MM. Humboldt and Bonpland, in travelling through the province of Quito, in South America, perceived them thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its explosions, along with water and heated vapour, which raised the thermometer to 210°, or only two degrees

[1] Letters on Natural Magic, p. 281, Amer. edit., New York, 1832.

[2] Girou de Buzareingues, Précis Élémentaire de Physiologie Agricole, p. 126, Paris, 1849.

short of the boiling point.[1] Dr. Reeve found living larvæ in a spring, whose temperature was 208°; Lord Bute saw confervæ and beetles in the boiling springs of Albano, which died when plunged into cold water; and Dr. Elliotson knew a gentleman, who boiled some honey-comb, two years old, and, after extracting all the sweet matter, threw the refuse into a stable, which was soon filled with bees.[2]

When the heating influence is applied to a part of the body only, as to the urethra, the temperature of the part, it has been affirmed, is not increased beyond the degree to which the whole body can be raised.

From all these facts, then, it may be concluded, that when the body is exposed to a temperature greatly above the ordinary standard of the animal, a frigorific influence is exerted; but this is effected at a great expense of vital energy; and hence is followed by considerable exhaustion, if the effort be prolonged. In the cold-blooded animal, the power of resisting heat is not great; so that it expires in water not hotter than the human blood occasionally is. M. Edwards found that a frog, which can live eight hours in water at 32°, is destroyed in a few seconds in water at 105°; this appears to be the highest temperature that cold-blooded animals can bear. Warm-blooded animals, when exposed to a high temperature, have their temperature increased to a certain extent; but whenever it passes this they perish. M. James[3] took two rabbits, whose normal temperature was about 102·2°, and placed them in two stoves, one at 212°, the other at 140°. The first died sooner than the second; but the temperature of each at the moment of death was the same, 111·2°. The same experiment, over and over again repeated, showed, that whatever might be the degree at which the heat was applied, the animal died when an increase of nine degrees was attained. In birds, whose normal temperature was 111·2°, the same at which the rabbits died, death ensued on the same increase of nine degrees, or when their blood reached 120·2°.

Observation has shown, that although the average temperature of an animal is such as we have stated in the table, particular circumstances may give occasion to some fluctuation. A slight difference exists, according to sex, temperament, idiosyncrasy, &c. MM. Edwards and Gentil found the temperature of a young female half a degree less than that of two boys of the same age. Edwards[4] tried the temperature of twenty sexagenarians, thirty-seven septuagenarians, fifteen octogenarians, and five centenarians, at the large establishment of Bicêtre, and observed a slight difference in each class. Dr. John Davy[5] found, that the temperature of a lamb was a degree higher than that of its mother; and in five new-born children, the heat was about half a degree higher than that of the mother, and it rose half a degree more in the first twelve hours after birth. He subsequently examined the temperature of the aged.[6] In eight old men and women, all, with one exception, between eighty-seven and ninety-five years of age, the

[1] Animal Physiology, Library of Useful Knowledge, p. 3.
[2] Physiology, p. 247, Lond., 1840.
[3] Gazette Médicale de Paris, 27 Avril, 1844.
[4] De l'Influence des Agens, &c., p. 436, Paris, 1826.
[5] Philosoph. Transact., p. 602. for 1814.
[6] Philosophical Transactions for 1844, p. 57.

temperature under the tongue was 98°, or 98·5°; therefore little, if at all, below the average of adult persons in like circumstances. Two observations, however, showed, that on exposure to external cold, the temperature was more reduced than in young persons. In one case it fell to 95°; in the other to 96·5°. A few observations were also made on persons working in rooms at a temperature of 92°: in one case, the temperature was 100°, in another 100·5°; and in a third, the external temperature being 73°, it was 99°. The same slight variations of the temperature of superficial parts in accordance with changes of external temperature were shown by repeated observations on a healthy man in the different seasons, at Constantinople. By moderate exercise, the temperature on the surface of the extremities was raised—but not above the general average—and was not affected in the internal parts.

Dr. G. C. Holland[1] found that the mean temperature of forty infants exceeded that of the same number of adults by 1¾°: twelve of the children had a temperature of from 100 to 103¼°. M. Edwards, on the other hand, found, that, in the warm-blooded animal, the faculty of producing heat is less, the nearer to birth; and that, in many cases, as soon as the young dropped from the mother, the temperature fell to within a degree or two of that of the circumambient air; and he moreover affirms, that the faculty of producing heat is at its minimum at birth, and increases successively to the adult age. His trials on children at the large *Hôpital des Enfans* of Paris, and on the aged at Bicêtre, showed that the temperature of infants, one or two days old, was from 93° to 95° of Fahrenheit; of the sexagenarian from 95° to 97°; of the octogenarian, 94° or 95°; and that, as a general rule, it varied according to age. In his experiments connected with this subject, he discovered a striking analogy between warm-blooded animals in general. Some of these are born with the eyes closed; others with them open: the former, until the eyes are opened, he found to resemble the cold-blooded animal; the latter—or those born with the eyes open—the warm-blooded. Thus, he remarks, the state of the eyes, although having no immediate connexion with the production of heat, may coincide with an internal structure which influences that function, and it certainly furnishes signs, which indicate a remarkable change in this respect; for, at the period of the opening of their eyes, all young mammalia have nearly the same temperature as adults. Now, in accordance with analogy, a new-born infant at the full period, having its eyes open, should have the power of maintaining a pretty uniform temperature during the warm seasons; but if birth should take place at the fifth or sixth month, the case is altered; the pupil is generally covered with the *membrana pupillaris*, which places it in a condition similar to that of closure of the eyelids in animals. Analogy, then, would induce us to conclude, that, in such an infant, the power of producing heat should be inconsiderable, and observation confirms the conclusion: although we obviously have not the same facilities, as in the case of animals, of exposing the infant to a depressed temperature. The temperature of a seven months' child, though well swathed, and near a good fire, was, within two or three hours after birth, no

[1] An Inquiry into the Laws of Life, &c., Edinb., 1829.

more than 89·6° Fahrenheit. Before the period at which this infant was born, the *membrana pupillaris* disappears; and it is probable, as M. Edwards has suggested, that if it had been born prior to the disappearance of the membrane, its power of producing heat might have been so feeble, that it would scarcely have differed from that of mammalia born with the eyes closed.[1]

An extensive series of experiments has been instituted by M. Roger,[2] in regard to the temperature of children in health and various diseases. In nine examinations from one to twenty minutes after birth, the temperature observed in the axilla was from 99·95° to 95·45.° Immediately after birth it was at the highest, but quickly fell to near the lowest point stated above. By the next day, however, it was entirely, or nearly, what it was before. The rapidity of the pulse and respiration appeared to have no certain relation to the temperature. In thirty-three infants, from one to seven days old, the most frequent temperature was 98·6°; the average 98·75°; the maximum—one case only—was 102·2°; the minimum—also one case—96·8°. All the infants were healthy. The frequency of respiration had no evident or constant relation to the temperature. A few of the infants were of a weakly habit; their average temperature was 97·7°: the others were strong, and their average temperature 99·534°. The age, at this period, had no influence on its temperature; nor had its sex, state of sleeping or waking, nor the period after sucking.

In twenty-four children, chiefly boys, from four months to fourteen years old, the most frequent temperature was above 98·6°; the average 98·978°; the minimum 98·15°; the maximum 99·95°. The average of those six years old, or under, was 98·798°; of those above six years, 99·158°. The average number of pulsations in the minute was, in those under six years, 102; above that age, 77; yet the temperature of the latter was higher than that of the former and of younger infants. There was no evident relation between the temperature and frequency of respiration; nor, in a few examinations, was the temperature affected in a regular way, by active exercise for a short time, or by the stage of digestion.

The state of the system, as to health or disease, also influences the evolution of heat. Dr. Francis Home,[3] of Edinburgh, took the heat of various patients at different periods of their indispositions. He found that of two persons labouring under the cold stage of an intermittent to be 104°; whilst, during the sweat and afterwards, it fell to 101°, and to 99°. In every case of severe rigor, Jochmann found[4] the temperature to rise. In one case, it speedily mounted from about 100° before the rigor to upwards of 103° during its continuance. The highest, which Dr. Home noticed in fever, was 107°. The author has witnessed it at 106° in scarlatina and in typhus, but it probably rarely exceeds this, although it is stated to have been as high as 112°;[5] and this is the point designated as "fever heat" on Fahrenheit's scale. In a case of double pleurisy, with tuberculosis of the lung, it was observed by Joch-

[1] Op. infra cit.
[2] Archiv. Général. de Médecine, Juillet, Août, 1844.
[3] Medical Facts and Experim., Lond., 1759.
[4] Op. cit., p. 73.
[5] G. T. Morgan's First Principles of Surgery, p. 80, Lond., 1837.

mann[1] as high as 105° nearly. M. Edwards alludes to a case of tetanus, in a child, the particulars of which were communicated to him by M. Prévost, of Geneva, in which the temperature rose to 110·75° Fahrenheit.[2] Mr. Hunter[3] found the interior of a hydrocele, on the day of operation, to be 92°; on the following day, when inflammation had commenced, it rose to 99°. The fluid obtained from the abdomen of an individual tapped for the seventh time for ascites indicated a temperature of 101°. Twelve days thereafter, when the operation was repeated for the eighth time, it was 104°. Dr. Granville[4] has asserted that the temperature of the uterus sometimes rises as high as 120°—the elevation seeming to bear some ratio to the amount of action in the organ. The author has frequently been struck with the seemingly elevated temperature of the vagina under those circumstances; but cannot help suspecting inaccuracy in the observations of Dr. Granville, the temperature which he indicates being so much higher than has ever been noticed in any condition of the system. Under this feeling, several experiments were made, at the author's request, by Dr. Barnes,[5] at the time one of the resident physicians of the Philadelphia Hospital, which exhibit only a slight difference between the temperature of the vagina and that of the uterus during parturition. In two cases, that of the labia was 100°, and in a third 105°; whilst that of the uterus was 100°, 102°, and 106°, respectively. Dr. James Currie had himself bled; and during the operation, the mercury of a thermometer, held in his hand, sank, at first slowly, and afterwards rapidly, nearly 10°; and when he fainted, the assistant found that it had sunk 8° farther. In diseased states, M. Roger[6] found that the temperature of the skin may descend in children to 74·3°, and rise as high as 108·5°. Its range is, consequently, greater than in adults, in whom M. Andral found it not to vary, in different diseases, more than from 95° to 107·6°. His estimates are, however, much too limited; as in Asiatic cholera the temperature has been marked as low as 67°, whilst in disease it has certainly risen as high as nearly 111° Fahrenheit.

MM. Edwards and Gentil assert, that they have likewise observed diurnal variations in the temperature, produced, apparently, by the particular succession in the exercise of the different organs; as where intellectual meditation was followed by digestion. The variations, they affirm, frequently amounted to two or three degrees between morning and evening.

Such are the prominent facts connected with the subject of animal heat. It is obvious, that it is disengaged by an action of the system, which enables it to counteract, within certain limits, the extremes of atmospheric heat and cold. The animal body, like all other substances, is subjected to the laws affecting the equilibrium, conduction, and radiation of caloric; but, by virtue of the important function we are now considering, its own temperature is neither elevated nor depressed by those influences to any great extent. Into the seat and nature of this

[1] Beobachtungen über die Körperwärme in chronischen fieberhaften Krankheiten, S. 15, Berlin, 1853.

[2] Edwards, op. citat., p. 490.

[3] On the Blood, &c., p. 296, Lond., 1794.

[4] Philos. Transact. for 1825, p. 262; and Sir E. Home, in Lect. on Comp. Anat., v. 201, Lond., 1828.

[5] American Medical Intelligencer, Feb. 15, 1839, p. 346.

[6] Op. cit.

mysterious process, and various ingenious theories that have been indulged in regard to it, we shall now inquire.

Physiologists have been by no means agreed as to the organs or apparatus of calorification. Some, indeed, have affirmed that there is not, strictly speaking, any such; and that it is a result of all the other vital operations. Amongst those, too, who admit the existence of such an apparatus, a difference of sentiment prevails; some thinking that it is *local* or effected in a special part of the organism; others, that it is *general* or disseminated through the whole economy. Under the name *caloricité*, M. Chaussier admitted a primary vital property, by virtue of which living beings disengage the caloric on which their proper temperature is dependent, in the same manner as they accomplish their other vital operations by distinct vital properties; and in support of the views, he adduced the circumstance, that each living body has its own proper temperature;—which is coexistent only with the living state; is common to every living part; ceases at death; and augments by every cause that excites the vital activity. It has been properly objected, however, to this view, that the same arguments would equally apply to many other vital operations,—and that it would be obviously improper to admit, for each of these functions, a special vital property. The notion has not experienced favour from the physiologist, and is, we believe, confined to the individual from whom it emanated.

So striking a phenomenon as animal temperature could not fail to attract early attention; and accordingly, we find amongst the ancients various speculations on the subject. The most prevalent was,—that its seat is in the heart; that the heart is communicated to the blood in that viscus, and is afterwards sent to every part of the system; and that the great use of respiration is to cool the heart. This hypothesis is liable to all the objections that apply to the notion of any organ of the body acting as a furnace,—that such organ ought to be calcined; and it has the additional objection, applicable to all speculations regarding the ebullition and effervescence of the blood as a cause of heat, that it is purely conjectural, without the slightest fact or plausible argument in its favour. It was not, indeed, until the chemical doctrines prevailed, that any thing like argument was adduced in support of the local disengagement of heat; the opinions of physiologists then settled almost universally upon the lungs; and this, chiefly, in consequence of its being observed, that animals, which do not breathe, have a temperature but little superior to the medium in which they live; whilst man and animals that breathe have a temperature considerably higher than the medium heat of the climate in which they exist, and one which is but little affected by changes in the thermal condition of that medium; and, moreover, that birds, which breathe, in proportion, a greater quantity of air than man, have a still higher temperature than he. Mayow,[1] whose theory of animal heat was, in other respects, sufficiently unmeaning, affirmed, that the effect of respiration is not to cool the blood, as had been previously maintained, but to generate heat, which it does by an operation analogous to combustion. It was not, however, until the promulgation of Dr. Black's doctrine of latent heat, that any plausible

[1] Tract. quinque, Oxon., 1674.

explanation of the phenomenon appeared. According to that distinguished philosopher, a part of the latent heat of the inspired air becomes sensible; consequently, the temperature of the lungs, and of the blood passing through them, must be elevated; and, as the blood is distributed to the whole system, it must communicate its heat to the parts as it proceeds on its course. But this view was liable to an obvious objection, which was, indeed, fatal to it, and so Dr. Black himself appears to have thought, from his silence on the subject. If the whole of the caloric were disengaged in the lungs, as in a furnace, and were distributed through the bloodvessels, as heated air is transmitted along conducting pipes, the temperature of the lungs ought to be much greater than that of the parts more distant from the heart; and so considerable as to consume that important organ in a short space of time.

The doctrine, maintained by MM. Lavoisier[1] and Séguin, was:—that the oxygen of the inspired air combines with the carbon and hydrogen of the venous blood, and produces combustion. The caloric given off is then taken up by the bloodvessels, and is distributed over the body. The arguments, which they urged in favour of this view, were:—the great resemblance between respiration and combustion, so that if the latter gives off heat, the former ought to do so likewise;—the generally admitted fact, that arterial blood is somewhat warmer than venous;—and certain experiments of Lavoisier and La Place,[2] which consisted in placing animals in the calorimeter, and comparing the quantity of ice which they melted, and, consequently, the quantity of heat, which they gave off, with the quantity of carbonic acid produced; and finding, that the quantity of caloric, which would result from the carbonic acid formed, was exactly that disengaged by those animals. Independently, however, of other objections, this hypothesis is liable to those already urged against that of Black, which it closely resembles. The objection, that the lungs ought to be much hotter than they really are—both absolutely and relatively—was attempted to be obviated by Dr. Crawford[3] in a most ingenious and apparently logical manner. The oxygen of the inspired air, according to him, combines with the carbon given out by the blood, so as to form carbonic acid. But the specific heat of this is less than that of oxygen; and accordingly a quantity of latent caloric is set free; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the water—which was supposed to be formed by the union of the hydrogen of the blood and the oxygen of the air—in the state of vapour, and to raise the temperature of the inspired air. So far the theory of Crawford was liable to the same objections as those of Black, and Lavoisier and Séguin. He affirmed, however, that the same process by which the oxygen of the inspired air is converted into carbonic acid, converts the venous into arterial blood; and as he assumed from his experiments, that the capacity of arterial blood for caloric is greater than that of venous, in the proportion of 1·0300 to 0·8928; he conceived, that the caloric, set free in the formation of the carbonic acid, in place of raising the tempera-

[1] Mém. de l'Acad. des Sciences pour 1777, 1780, and 1790.

[2] Mémoir. de l'Acad. des Sciences pour 1780.

[3] Experiments and Observations on Animal Heat, &c., 2d edit., London, 1788; and Fleming, Philosophy of Zoology, i. 387, Edinb., 1822.

ture of the arterial blood, is employed in saturating its increased capacity, and maintaining its temperature at the same degree with the venous. According to this view, therefore, the heat is not absolutely set free in the lungs, although arterial blood contains a greater quantity of caloric than venous; but when, in the capillaries, the arterial becomes converted into venous blood, or into blood of a less capacity for caloric, the heat is disengaged, and this occasions the temperature of the body.

Were the facts, which served as a foundation for this beautiful theory true, the deductions would be irresistible; and, accordingly, it was at one time almost universally received, especially by those who consider, that all vital operations can be assimilated to chemical processes; and it is still favoured by many. "The animal heat," observes a recent writer,[1] "has been accounted for in different ways by several ingenious physiologists; from the aggregate of their opinions and experiments, I deduce, that heat is extricated all over the frame, in the capillaries, by the action of the nerves, during the change of the blood, from scarlet arterial to purple venous; and also whilst it is changing in the lungs from purple to scarlet. There is a perpetual deposition by the capillary system of new matter, and decomposition of the old all over the frame, influenced by the nerves; in this decomposition there is a continual disengagement of carbon, which mixes with the blood returning to the heart, at the time it changes from scarlet to purple; this decomposition, being effected by the electric agency of the nerves, produces a constant extrication of caloric; again, in the lungs that carbon is thrown off and united with oxygen, during which caloric is again set free, so that we have in the lungs a charcoal fire constantly burning, and in the other parts a wood fire, the one producing carbonic acid gas, the other carbon, the food supplying through the circulation the vegetable (or what answers the same end, animal) fuel, from which the charcoal is prepared which is burned in the lung."

Numerous objections have, however, been made against the view of Crawford. In the *first* place, it was urged, that our knowledge is limited to the fact, that oxygen is taken into the pulmonary vessels, and carbonic acid given off, but that we have no means of knowing whether the one goes immediately to the formation of the other. Dr. Crawford had inferred from his experiments, that the specific heat of oxygen is 4·7490; of carbonic acid, 1·0454; of nitrogen, 0·7936; and of atmospheric air, 1·7900; but the more recent experiments of MM. Delaroche and Bérard make that of oxygen, 0·2361; carbonic acid, 0·2210; of nitrogen, 0·2754; and of atmospheric air, 0·2669; a difference of such trifling amount, that it has been conceived the quantity of caloric, given out by oxygen during its conversion into carbonic acid, would be insufficient to heat the residual air in the lungs to its ordinary elevation. *Secondly.* The elevation of temperature of one or two degrees, which appears to take place in the conversion of venous into arterial blood, although generally believed, is not demonstrated. The experiments instituted on this point have been few and imprecise; and those of MM. Becquerel and Breschet,[2] made by introducing deli-

[1] Billing, First Principles of Medicine, 2d edit., p. 19, London, 1837.
[2] Comptes Rendus, Oct., 1841.

cate thermometers into the auricles of the heart of dogs, invariably gave the temperature of arterial, only a few fractions of a degree higher than that of venous, blood. A *coup-de-grace* has, however, been given to this view by the experiments of Prof. Bernard, who constantly found the blood of the right ventricle warmer than that of the left. Without opening the chest, he introduced in succession the same thermometer into the right and the left ventricle by passing the instrument into the jugular vein and the brachio-cephalic trunk. The operation was performed on fifteen living sheep; seven times the thermometer was introduced at first into the right ventricle and then into the left; and eight times the order was reversed. The result was the same in all. From his experiments on dead animals M. Bernard accounts for the temperature of the blood in the left side of the heart having been rated higher than that in the right side by the fact of the comparative thinness of the parietes of the right side allowing of the blood being sooner cooled by refrigerating influences—as the admission of cold air.[1] From these researches it is difficult to avoid the inference by M. Gavarret, that the researches of M. Bernard establish incontestably, that the blood is cooled in passing through the lungs; and that, normally, the temperature of the left cavities of the heart is inferior to that of the right; a fact, which had been discovered in 1832 by M. Malgaigne, by passing the thermometer into the cavities of the heart in the same manner as was done by M. Bernard. *Thirdly*. M. Dulong,[2]—on repeating the experiments of Lavoisier and La Place, for comparing the quantities of caloric given off by animals in the calorimeter with that which would result from the carbonic acid formed during the same time in their respiration—did not attain a like result. The quantity of caloric disengaged by the animal was always superior to that which would result from the carbonic acid formed. *Fourthly*. The estimate of Crawford regarding the specific heat of venous and arterial blood has been contested. He made that of the former, we have seen, 0·8928; of the latter, 1·0300. The result of the experiments of Dr. John Davy[3] give 0·903 to the former, and 0·913 to the latter; and in another case, the result of which has been adopted by M. Magendie, the specific heat of venous was greater than that of arterial blood, in the proportion of ·852 to ·839. Granting, however, the case to be as stated by Crawford, it is insufficient to explain the phenomena. It has, indeed, been attempted to show, that if the whole of the caloric, set free in the manner mentioned, were immediately absorbed, it would be insufficient for the constitution of the arterial blood; and that, instead of the lung running the risk of being calcined, it would be threatened with congelation. *Lastly*, the accurate experiments of Edwards, Magnus and others elsewhere referred to, by demonstrating the larger amount of oxygen in the arterial blood, and of carbonic acid in the venous blood; have shown that the oxygen of the atmosphere unites with the carbon in every part of the system of nutrition; and not in the lungs exclusively.

[1] Gavarret, De la Chaleur produite par les Etres Vivants, p. 110, Paris, 1855. Notes of M. Bernard's Lectures on the Blood, &c., by Walter F. Atlee, M. D., pp. 23 and 140, Philad., 1854.

[2] Magendie's Journal de Physiologie, iii. 45.

[3] Philos. Transactions for 1814.

The theory of combustion in the lungs is still, however, maintained by many physiologists,[1] and an able writer of this country, Dr. Metcalfe,[2] from a consideration of the various facts observed by himself and others, thinks we are authorized to conclude;—*first*, that during the passage of dark venous blood through the lungs, it gives off variable proportions of carbon and hydrogen, which unite chemically with atmospheric oxygen to form carbonic acid and water as in ordinary combustion, by which it acquires an addition of caloric, and a bright florid hue; and *secondly*, that during its circulation through the systemic capillaries, the caloric obtained from the atmosphere is transferred to the solids, by which their temperature and vitality are maintained; and the blood returns to the heart of a dark modena hue, having lost its power of stimulating the organs, until it acquires an additional quantity of caloric from the lungs.

Dr. Spencer,[3] formerly of Geneva College, N. Y., who regards the great end and function of respiration to be, to aid, both directly and indirectly, in the office of the generation and diffusion of animal heat, maintains, that the substance thrown off from the venous blood in respiration is hydrate of carbon:—that the carbon, on coming in contact with atmospheric oxygen combines with it, forming carbonic acid, which is exhaled from the lungs and skin by expiration and perspiration;—that the amount of latent heat of the oxygen employed is much greater than that of the carbonic acid formed in the lungs, and hence caloric is set free, which imparts heat to the blood and surface; that this free heat also combines with the water of the hydrate of carbon and converts it into vapour;—that the lungs and cutaneous surface aid in regulating animal temperature by the conversion of water into vapour, thus conveying off any excess of free caloric in the system, by combining with it in the form of latent heat;—that the water of the hydrate of carbon is converted into vapour in the lungs, and upon the surface, precisely as when wood is burned, and hence assumes the form of insensible respiratory and perspiratory transpiration;—and that the systemic red capillaries are the antagonists of the pulmonary; and are constantly decomposing carbonic acid, and forming, with water, hydrate of carbon,—or, in other words, carbonizing the blood; from which union water and carbonic acid are transformed into a solid substance, and hence latent becomes free heat, at every point where red blood circulates. The views of Dr. Spencer are ingenious, but far from convincing; and are presented by him, although aphoristically, in some detail. He objects to the view, which holds that hydro-carbon is thrown off from the blood in the lungs by its union with oxygen, because hydro-carbon is an imaginary compound. The same objection, however, applies to his hydrate of carbon, which, he thinks, exists in the blood in the solid state, and is analogous to, if not identical with, the lignin of vegetables. In regard to his opinion, that the systemic red capillaries are the antagonists of the pulmonary capillaries, it must not be forgotten, that there are also red capillaries

[1] Nasse, Art. Thierische Wärme, in Wagner's Handwörterbuch der Physiologie; 23ste Lieferung, S. 1, Braunschweig, 1849.
[2] Caloric, its Mechanical, Chemical, and Vital Agencies, &c., ii. 555, London, 1843.
[3] Lectures on Animal Heat, Geneva, N. Y., 1845.

in the lungs; and that in the system of nutrition every where arterial is converted into venous blood; and doubtless with the same phenomena.

The pulmonary combustion theory has received the powerful support of Liebig, and many elucidations and expansions from that distinguished chemist. According to him, the carbon and hydrogen of the food, in being converted, through the agency of oxygen, into carbonic acid and water, must give out as much heat as if these gases were burned in the open air. The temperature of the human body is essentially the same in the torrid as in the frigid zone; but as the body may be regarded in the light of a heated vessel, which cools with the greater rapidity the colder the surrounding medium, the fuel, necessary to maintain its heat, must vary in different climates. How unequal must be the loss of heat at Palermo, where the external temperature is nearly equal to that of the body, and in the polar regions, where the external temperature is from 70° to 90° lower. In the animal body, food is fuel, and with a proper supply of oxygen we obtain the heat during its oxidation or combustion. In winter, when we take exercise in a cold atmosphere, and the amount of inspired oxygen consequently increases, the necessity for food containing carbon and hydrogen increases in the like ratio, and, by gratifying the appetite thus excited, we obtain the most efficient protection against piercing cold. A starving man is soon frozen to death; and every one, says Liebig, knows, that the animals of prey in the Arctic regions far exceed those of the torrid zone in voracity. Our clothing is merely an equivalent for a certain amount of food. Were we to go naked, like certain savage tribes, or exposed in hunting or fishing to the same degree of cold as the Samoyedes, we should be able to consume with ease sixteen pounds of flesh, and perhaps a dozen tallow candles, as travellers have related of those people. We should, also, be able to take the same quantity of brandy or train-oil without bad effects, because the carbon and hydrogen of these substances would only suffice to keep up the equilibrium between the external temperature and that of our bodies. The whole process of respiration, he thinks, is clearly exhibited when we view the condition of man or animals under abstinence from food. Oxygen is abstracted from the air, and carbonic acid and water expired, because the number of respirations remains unaltered. With the continuance of the abstinence the carbon and hydrogen of the body diminish. The first effect of abstinence is the disappearance of the fat, which can be detected neither in the scanty fæces nor urine; its carbon and hydrogen are thrown off by the skin and lungs, in the form of a compound of oxygen. These constituents, then, have served for the purposes of respiration. Every day, 32½ ounces of oxygen are inspired; and these must remove their equivalents of carbon to form carbonic acid. When this combination ceases to go on, respiration terminates: death has ensued. The time required for starving an animal to death depends on its fatness, state of activity, the temperature of the air, and the presence or absence of water. That the quantity of heat evolved by the combustion of 13·9 ounces of carbon is amply sufficient to account for the temperature of the human body, may be estimated by figures. An ounce of carbon burned, according to the experiments of Despretz, would evolve 14067 degrees of heat; and 13·9 oz. would, therefore, give out 195531·3 degrees of heat. This would suffice to boil 67·9 pounds of water at 32°, or to convert 11·4 pounds of water at 98·3° into vapour. If we consider the quantity of water vaporized through the skin to be, in twenty-four hours, 48 ounces or 3 pounds, there will then remain, after deducting the necessary amount of heat, 144137·7 degrees of heat, which are dissipated by radiation in heating the expired air, and in excrementitious matters.[1]

The views of Liebig necessarily attracted the devout attention of the chemical physiologist, and whilst they have met with unqualified support from some, they have been as much condemned by others, who appear to have a horror at the introduction of chemical explanations to account for vital phenomena. Yet it cannot be contested, that the function of calorification is an act of vital chemistry; and, consequently, although the views of Liebig may fail to convince, they certainly have taken the proper direction, and, all must grant, have been plausibly and ably supported. The division of aliments by him into the nitrogenized or plastic elements of nutrition, and the non-nitrogenized or elements of respiration and calorification, has been referred to elsewhere[2] and been the subject of comment in other relations. It appears that no doubt ought to exist in regard to nitrogenized food being inservient to the production of heat. Some of the animals, which are purely carnivorous, are noted for their elevated temperature in the coldest climates and seasons; and the large amount of nitrogenized material necessary to relieve the feeling of debility—not of hunger—in the voyages to Arctic regions confirms this view. Dr. Kane informed the author, that in his last voyage to those regions, to produce a feeling of satiety, six or eight ducks in the day were needed. Yet it was not hunger that was experienced, but an overwhelming sense of debility that could be relieved in no other manner.

It has been objected to the theory of Liebig, that if even it were admitted to be applicable to mammalia, birds, and reptiles, it by no means follows, that it should be so to animals that respire by means of branchiæ or gills, all of which consume little oxygen, comparatively speaking; yet many of them devour enormous quantities of food. Even the largest and most voracious of the reptiles, as alligators, crocodiles, &c., under a burning climate too, breathe feebly with their vesicular lungs, and consume but little oxygen. Fishes, too, whose blood is but imperfectly oxygenized by their branchial apparatus, are perhaps amongst the most voracious of animals; yet, according to this theory, they ought to eat little, because they consume little oxygen. These and other facts were eagerly urged by M. Virey,[3] as objections to the views of the then Professor of Giessen. It may be replied, however, that in such cases a large portion of the carbon must pass off in the excrements. There is no country in the world, according to Madame Calderon de la Barca,[4] where so much animal food is consumed as in

[1] Animal Chemistry, Amer. edit. by Webster, p. 33, Cambridge, 1842.
[2] Page 115.
[3] Journal de Pharmacie, Mai, 1842.
[4] Life in Mexico, vol. i. p. 152, Boston, 1842.

Mexico, "and there is no country in which so little is required." To this and to want of exercise she ascribes the early fading of beauty in the higher classes, the decay of teeth, and the over-corpulency so common amongst them; and in regard to the last she is, doubtless, correct.

To the statement of Liebig respecting the greater voraciousness of the animals of prey of the Arctic regions, it has been replied,[1] that a Bengal tiger or Cape hyena requires, in proportion to its size, quite as much aliment as any of the Arctic carnivora; and that the vultures of Hindostan and Persia exceed, perhaps, all other animals in gluttony. The voraciousness of the shark, too, even within the tropics, is proverbial. "Those who ride over the Pampas in South America," says Dr. Graves, "at the rate of one hundred miles a day, exposed to a burning sun, subsist entirely on boiled beef and water, without a particle of vegetable food of any kind, and yet they attain to an extraordinary *condition*, and capability of enduring violent and long-continued exertion. Liebig's theory must be very ductile, if it can explain how it happens, that an exclusively animal diet agrees with man quite as well at the equator as within the Arctic circle."[2] Numerous facts, indeed, can be brought forward of an opposite tendency to those of Liebig, which render it impracticable for us, in the present state of our knowledge, to embrace all his positions. Under Respiration, the theory, supported by him, that the blood corpuscles are the carriers of oxygen from the lungs to the tissues, and the conveyers of carbonic acid back from the tissues to the lungs, was mentioned. Were this view tenable it would seem, that if the amount of blood corpuscles should become diminished from any cause, the function of calorification ought to be impaired to a like extent. To discover what effect would be produced on the temperature of the living body by a diminution in the quantity of blood corpuscles, M. Andral instituted some experiments, which showed, that the temperature remained normal, even in cases in which the corpuscles had experienced the greatest diminution in number. In the axilla, the temperature was 98° or 99° of Fahrenheit in persons, the proportion of whose blood corpuscles was not higher than 50, 40, 30, and even 21 parts in the 1000; the healthy ratio being 127. Indeed, notwithstanding the great depression in anæmic patients, the heat rose, as usual, when they were attacked with fever, to which they are as subject as other individuals.[3]

But the combustion theories of calorification were most seriously assailed by experiments, tending to show, that the function of calorification is derived from the great nervous centres. When an animal is decapitated, or the spinal marrow, or the brain, or both, are destroyed, the action of the heart may still be kept up, provided the lungs be artificially inflated. In such case, it is found, that the usual change in the blood, from venous to arterial, is produced; and that oxygen is absorbed and carbonic acid exhaled as usual. Sir Benjamin Brodie,[4] in performing this experiment, directed his attention to the point—whe-

[1] R. J. Graves, A System of Clinical Medicine, p. 57, Dublin, 1843.
[2] See, on all this subject, Metcalfe on Caloric, vol. ii. chap. 2, London, 1843.
[3] Andral, Hématologie Pathologique, p. 60, Paris, 1843.
[4] Philos. Trans. for 1811 and 1812; and Physiological Researches, p. 1–37, Lond., 1851.

ther animal heat is evolved under such circumstances, and the temperature maintained, as where the brain and spinal marrow are entire—and he found, that although the blood appeared to undergo its ordinary changes, the generation of animal heat seemed to be suspended; and consequently, if the inspired air happened to be colder than the body, the effect of respiration was to cool the body; so that an animal, in which artificial respiration had been kept up, became sooner cold than one killed and left undisturbed. The inference from these experiments, was, that instead of circulation and respiration maintaining heat, they dissipate it; and that as the heat is diminished by the destruction of the nervous centres, its disengagement must be ascribed to the action of those centres, and especially to that of the encephalon.

Thirty years ago, M. Chossat[1] endeavoured to discover the precise part of the nervous system that is engaged in calorification; but the results of his experiments were not such as to induce him to refer it exclusively, with Sir B. Brodie, to the encephalon. He divided the brain, anterior to the pons Varolii, in a living animal, so that the eighth nerve was uninjured. Respiration, consequently, continued, and inflation of the lungs was unnecessary. Notwithstanding this serious mutilation, the circulation went on; and M. Chossat observed distinctly, that arterial blood circulated in the arteries. Yet the temperature of the animal gradually sank, from 104° Fahr.,—its elevation at the commencement of the experiment,—to 76°, in twelve hours, when the animal died. It seemed manifest to M. Chossat, that, from the time the brain was divided, heat was no longer given off, and the body gradually cooled, as it would have done after death. He, moreover, noticed, that the time, at which the refrigeration occurred most rapidly was that in which the circulation was most active,—at the commencement of the experiment. In other experiments, M. Chossat paralysed the action of the brain by violent concussion, and injected a strong decoction of opium into the jugular vein,—keeping up artificial respiration. The results were the same. From these experiments, he drew the conclusion, that the brain has a direct influence over the production of heat.

His next experiments were directed to the discovery of the medium through which the brain acts,—the eighth pair of nerves, or spinal marrow. He divided the eighth pair in a dog, and kept up artificial respiration. The temperature sank gradually; and, at the expiration of sixty hours, when the animal died, it was reduced to 68° of Fahrenheit. Yet death did not occur from asphyxia or suspension of the phenomena of respiration; for the lungs crepitated, exhibited no signs of infiltration, and were partly filled with arterial blood. The animal appeared to M. Chossat to expire from cold. As, however, the mean depression of heat was less than in the preceding experiments, he inferred that a slight degree of heat is still disengaged after the section of the eighth pair; whilst, after injury done to the brain directly, heat is no longer given off. Again, he divided the spinal marrow beneath the occiput, and although artificial respiration was maintained, as in the experiments of Sir B. Brodie, the temperature gradually fell, and the animal died ten hours afterwards, its heat being 79°; and as death occurred

[1] Sur la Chaleur Animale, Paris, 1820, and Adelon, op. cit., iii. 416.

in this case so much more speedily than in the last, he inferred, that the influence of the brain over the production of heat is transmitted rather by the spinal marrow than by the eighth pair. In his farther experiments, M. Chossat discovered, when the spinal marrow was divided between each of the twelve dorsal vertebræ, that the depression of temperature occurred less and less rapidly, the lower the intervertebral section, and at the lowest was imperceptible; he, therefore, concluded, that the spinal marrow does not act directly in the function, but indirectly through the trisplanchnic nerve. To satisfy himself on this point, he opened the left side of a living animal, beneath the twelfth rib, and removed the left supra-renal capsule, dividing the trisplanchnic where it joins the semilunar plexus. The animal lost its heat gradually, and died ten hours afterwards in the same condition, as regarded temperature, as when the spinal marrow was divided beneath the occiput. Desiring to obtain more satisfactory results,—the last experiment applying to only one of the trisplanchnic nerves,—he tied the aorta, which supplies both, beneath the place where it passes through the arch of the diaphragm, at the same time preventing asphyxia by inflating the lungs. The animal lost its heat much more rapidly; and died in five hours. In all these cases, according to M. Chossat, death occurred from cold; the function, by which the caloric, constantly abstracted from the organism by the surrounding medium, is generated having been rendered impracticable. To obtain a medium of comparison, he killed several animals by protracted immersion in cold water, and found, that the lowest temperature to which the warm-blooded could be reduced, and life persist, was 79° of Fahrenheit. He also alludes to cases of natural death by congelation, which, he conceives, destroy in the manner before suggested,—that is, by impairing the nervous energy, as indicated by progressive stupor, and debility of the chief functions of the economy. Lastly:—on killing animals suddenly, and attending to the progress of refrigeration after death, he found it to be identical with that which follows direct injury of the brain, or the division of the spinal marrow beneath the occiput. A view somewhat analogous to this of M. Chossat, was embraced by Sir Everard Home.[1] He considered, that the phenomenon is restricted to the ganglionic part of the nervous system; resting his opinion chiefly on the circumstance, that there are animals, which have a brain, or some part equivalent to one, and whose temperature is not higher than that of the surrounding medium; whilst all the animals that evolve heat are provided with nervous ganglia.[2]

The doctrines of Brodie, Chossat, and Home have been considered by the generality of the chemists—by Brande,[3] Thomson,[4] and Paris,[5]—to be completely subversive of the chemical view, which refers the production of animal heat to respiration; and their position,—that it is a nervous function,—has seemed to be confirmed by the facts attendant

[1] Philos. Trans., p. 257, for 1825; Journal of Science and Arts. xx. 307; and Lect. on Comparative Anat., v. 121 and 194. Lond., 1828.

[2] See, on the effect of diminution of its temperature on the life of an animal, Dr. Brown-Séquard, in Med. Examiner, Sept., 1852, p. 550.

[3] Manual of Chemistry, vol. iii.

[4] System of Chemistry, vol. iv.

[5] Medical Chemistry, p. 327, Lond., 1825.

upon injury done to the nerves of parts, and by what is witnessed in paralytic limbs, the heat of which is generally and markedly inferior to that of the sound. But there are many difficulties in the way of admitting, that the nervous system is the special organ for the production of animal temperature. Dr. Wilson Philip,[1] from a repetition of the experiments of Sir Benjamin Brodie, was led to conclude, that the cause of the temperature of the body diminishing more rapidly, when artificial inflation was practised, than when the animal was left undisturbed, was—too large a quantity of air having been sent into the lungs; for he found, when a less quantity was used, that the cooling process was sensibly retarded by the inflation. The experiments of Legallois,[2] Hastings,[3] and Williams,[4] although differing from each other in certain particulars, corroborate the conclusion of Dr. Philip; and, what is singular, appear to show, that the temperature occasionally *rises* during the experiment; a circumstance which tends rather to confirm the view, that respiration is concerned materially in the evolution of heat.

Many of the facts detailed by M. Chossat are curious, and exhibit the indirect agency of the nervous system; but his conclusion, that the trisplanchnic is the great organ for its developement, is liable to the objections already brought against the theory, which looks upon the lungs as a furnace for the disengagement of caloric,—that they ought to be consumed in a short space of time. All the facts, however, clearly show, that, in the upper classes of animals, the three great acts of innervation, respiration, and circulation are indirectly concerned in the function; but not that any one of them is the special seat. M. Edwards has maintained, that it is more connected with the second of these than with either of the others. Thus, animals, he argues, whose temperature is highest, bear privation of air least: cold-blooded animals suffer comparatively little; and young animals are less affected than the adult. Now, the greater the temperature of the animal, and the nearer the adult age, the greater is the consumption of oxygen. He further observed, that whilst season modifies calorification, it affects also respiration; and if, in summer, less heat be elicited, and in winter more, it is found that respiration consumes less oxygen in the former than in the latter season.

The experiments of M. Legallois, as well as those instituted by M. Edwards, led the latter to infer, that there is a certain ratio between heat and respiration in both cold-blooded and warm-blooded animals, and in hibernating animals both in the periods of torpidity and full activity. When the eighth pair of nerves is divided in the young of the mammalia, a considerable diminution is produced in the opening of the glottis; so that, in puppies recently born, or one or two days old, so little air enters the lungs, that when the experiment is made under ordinary circumstances the animal perishes as quickly as if it were entirely deprived of air. It lives about half an hour. But, if the same operation be performed upon puppies of the same age benumbed

[1] An Experimental Inquiry into the Laws of the Vital Functions, 3d edit., p. 180.
[2] Annales de Chimie, iv. 5, Paris, 1817.
[3] Wilson Philip, op. cit.; and Journal of Science, &c., xiv. 96.
[4] Edinburgh Medico-Chirurgical Transactions, ii. 192.

with cold, they live a whole day. In the first case M. Edwards thinks, and plausibly, the small quantity of air is insufficient to counteract the effect of the heat, whilst, in the other, it is sufficient to prolong life considerably; and he draws the following practical inferences applicable to the adult age, and particularly to man. A person is asphyxied by an excessive quantity of carbonic acid in the air he breathes; the pulse is no longer perceptible; the respiratory movements cannot be discerned, but his temperature is still elevated. How should we proceed to recall life? Although the action of the respiratory organs is no longer perceptible, all communication with the air is not cut off. It is in contact with the skin, on which it exerts a vivifying influence: it is also in contact with the lungs, in which it is renewed by the agitation constantly taking place in the atmosphere, and by the heat of the body, which rarefies it. The heart continues to beat, and a certain degree of circulation is kept up, although not perceptible by the pulse. The temperature of the body is too high to allow the feeble respiration to produce upon the system all the effect of which it is capable. The temperature must, therefore, be reduced; the patient withdrawn from the deleterious atmosphere; be stripped of his clothes, in order that the air may have a more extended action upon his skin; be exposed to the cold, although it be winter, and cold water be thrown upon his face until the respiratory movements reappear. This is precisely the treatment adopted to revive an individual from a state of asphyxia. If, instead of cold, continued warmth were to be applied, it would be one of the most effectual means of extinguishing life,—a consequence which, like the former, is confirmed by experience. In sudden faintings, when the pulse is weak or imperceptible, the action of the respiratory organs diminished, and sensation and voluntary motion suspended, persons, the most ignorant of medicine, are aware, that means of refrigeration must be employed,—such as exposure to air, ventilation, and sprinkling with cold water. In violent attacks of asthma, also, when the extent of respiration is so limited that the patient experiences a sense of suffocation, he courts the cold air even in the severest weather; opens the windows; breathes a frosty air, and finds himself relieved.

As a general rule, an elevated temperature accelerates the respiratory movements, but the degree of temperature requisite to produce this effect is not the same in all persons. The object of the accelerated respiration is, that more air may come in contact with the lungs in a given time, so as to reanimate what the heat depresses. It is proper to remark, however, that we meet with many exceptions to the rule endeavoured to be laid down by M. Edwards as regards the constant ratio between heat and respiration. Experiments on the lower animals, and pathological cases in man, have shown, that lesions of the upper part of the spinal marrow give occasion, at times, to an extraordinary developement of heat. In the case of a man at St. George's Hospital, London, labouring under a lesion of the cervical vertebræ, Sir B. Brodie observed the temperature to rise to 111°, at a time when the respirations were not more than five or six in a minute.[1] Drs. Graves and Stokes[2] give the case of a patient who

[1] London Medical Gazette for June, 1836.

[2] Dublin Hospital Reports, vol. v.; and Dr. Graves, Clinical Lectures, American Med. Lib. edit., p. 126, Philad., 1838.

laboured under very extensive developement of tubercles, had tubercular abscesses in the upper portions of both lungs, and general bronchitis. In this case, at a period when the skin was hotter than usual, and the pulse 126, the respirations were only 14 in a minute. Besides, as Dr. Alison[1] has remarked, the temperature of the body is not raised by voluntarily increasing or quickening the acts of respiration, but by voluntary exertions of other muscles, which accelerate the circulation, and thus necessitate an increased frequency of respiration;—a fact, which would seem to show, that calorification is dependent not simply on the application of oxygen to the blood, but on the changes that take place during the circulation, and to the maintenance of which its oxygenation is one essential condition. Moreover, in the fœtus in utero, there is, of course, no respiration; yet its temperature equals, and indeed is said to even exceed, that of the mother; and we know that its circulation is more rapid, and its nutrition more active.[2]

That innervation is indirectly concerned in the phenomenon is proved by the various facts, which have been referred to; and Legallois, although he does not accord with Sir B. Brodie, conceives that the temperature of the body is greatly under the influence of the nervous system, and that whatever weakens the nervous power, proportionally diminishes the capability of producing heat. Dr. Philip, too, concluded from his experiments, that the nervous influence is so intimately connected with the power of evolving heat, that it must be looked upon as a necessary medium between the different steps of the operation. He found, that if the galvanic influence be applied to fresh-drawn arterial blood, an evolution of heat, amounting to three or four degrees, takes place; at the same time, the blood assumes the venous hue, and becomes partly coagulated. He regards the process of calorification as a secretion; and explains it upon his general principle of the identity of the nervous and galvanic influences, and the necessity for the exercise of such influence in the function of secretion.

Mr. H. Earle[3] found the temperature of paralysed limbs slightly lower than that of sound limbs, and the same effect is observed to supervene on traumatic injuries of the nerves. In a case of hemiplegia, of five months' duration, under the author's care at the Blockley Hospital, the thermometer in the right—the sound—axilla of the man stood at 96½°; in the axilla of the paralysed side, at 96°. The difference in temperature of the hands was more marked—that of the right being 87°, whilst that of the left was only 79½°. In another case—that of a female—of two weeks' duration, accompanied with signs of cerebral turgescence, the temperature in the axilla of the sound side was 100°; in that of the paralysed 98·25°: of the hand of the sound side, 94°; of the other, 90°. It is a general fact, that the

[1] Outlines of Physiology, Lond., 1831.

[2] On the connexion of respiration with calorification, see P. H. Bérard, art. Chaleur Animale, in Dict. de Méd., 2de édit., vii. 175, Paris, 1834; and Mr. Newport on the Temperature of Insects, and its Connexion with the Functions of Respiration and Circulation in this Class of Invertebrated Animals, Philos. Transact., part ii. 4to. p. 77, Lond., 1837.

[3] Medico-Chirurgical Transactions, vii. 173, Lond., 1819.

temperature of the paralysed side in hemiplegia is less than that of the sound; yet the irregularity of nervous action is so great, and the power of resistance to excitant or depressing agents so much diminished, that the author has not unfrequently found it more elevated.[1] In such cases, moreover, the nutrition of the limb will fall off, in consequence of the want of exercise; and this circumstance might account for any diminution of temperature manifested.

Many singular phenomena, as regards the function of calorification, are produced by injuries of the nervous centres, or by a division of nerves proceeding to a part. Thus, one of the first effects of division of the spinal cord in the back is to raise the temperature of the posterior part of the body;[2] and the elevation continues for some hours. A case is described by Sir Benjamin Brodie[3] of severe injury of the cord on the lower part of the cervical region, which paralyzed the whole of the nerves passing off below the injured part, yet the temperature of the inside of the groin was not less than 111°; although respiration was imperfectly executed, the number of respirations considerably diminished and the countenance livid. Budge,[4] too, found, that if the spinal cord was extirpated on one side between the last cervical and the third thoracic vertebra, the temperature of the corresponding side of the face rose in from ten to fifteen minutes. Prof. Bernard[5] and Dr. Brown-Séquard[6] observed, that an elevation of temperature took place on one side of the face, when the trunk which unites the cervical ganglia of the sympathetic of that side was divided. The same phenomena resulted, and in a greater degree, when the superior cervical ganglion was removed; and they continued for months. It has been suggested by the latter physiologist, that the phenomena are owing to the induced paralysis and the consequent dilatation of the bloodvessels; the blood reaches the part supplied by the nerve in greater quantity, and nutrition is therefore more active. The increased sensibility of the part he considers to be the result of the augmented vital properties of the nerves when their nutrition is increased. It is difficult to account satisfactorily for the phenomena; but they are, doubtless, owing to modified nutritive action in the parts.

Lastly, that the circulation is necessary to calorification, we have evidence in the circumstance, that if the vessels proceeding to a part be tied, animal heat is no longer disengaged from it. It has been seen, however, that there is no certain ratio between the heat and frequency of the pulse.

It is manifest, then, that in animals, and especially in the warm-blooded, the three great vital operations are necessary for the disen-

[1] American Med. Intelligencer, Oct. 15, 1338, p. 252.

[2] Brown-Séquard. Med. Examiner, March, 1853, p. 138.

[3] Med. Gazette, June, 1836; and Physiological Researches, p. 121, Lond. 1851.

[4] Memoranda der Speciellen Physiologie des Menschen, 5te Auflage, S. 143, Weimar, 1853.

[5] Gazette Médicale, 21 Févr., 1852; and Notes of M. Bernard's Lectures on the Blood, by Walter F. Atlee, M. D., p. 164, Philad., 1854.

[6] Med. Examiner, August, 1852, p. 489; and ibid., Mar., 1853, p. 140; and Sur les Resultats de la Section et de la Galvanisation du Nerf Grand Sympathique au Cou, Gazette Méd. de Paris, Année, 1854. See, also, Dr. J. Drummond, Art. Sympathetic Nerve, in Cyclop. of Anat. and Physiol., pt. xlvii., p. 470, Lond., Aug., 1855.

gagement of the due temperature, but we have no sufficient evidence of the direct agency of any one: whilst we see heat elicited in the vegetable, in which these functions are at all events rudimental; and the existence of one of them—innervation—more than doubtful.

The views of those who consider, that the disengagement of caloric occurs in the intermediate system, or in the system of nutrition of the whole body, appear to be most consistent with observed phenomena. These have varied according to the physical circumstances, that have been looked upon as producing heat. By some, it was regarded as the product of an effervescence of the blood and humours; by others, as owing to the disengagement of an igneous matter or spirit from the blood; by others ascribed to an agitation of the sulphureous parts of the blood; whilst Boerhaave[1] and Douglas[2] ascribed it to the friction of the blood against the parietes of the vessels, and of the corpuscles against each other.

In favour of the last hypothesis, it was urged, that animal heat is in a direct ratio with the velocity of the circulation, the circumference of the vessels, and the extent of their surface; and that we are thus able to explain, why the heat of parts decreases in a direct ratio with their distance from the heart; whilst the greater heat of the arterial blood in the lungs was accounted for by the supposition, that the pulmonary circulation is far more rapid. Most of these notions—it need scarcely be said—were entirely hypothetical. The data were generally incorrect, and the deductions characteristic of the faulty physics of the period in which they were hazarded. The correct view, it appears to us, is, that caloric is disengaged in every part, by a special chemico-vital action, modified in animals by the nervous influence. In this manner, calorification becomes a function executed in the whole system of nutrition; and, therefore, appropriately considered in this place. It has been remarked by Tiedemann,[3] that the intussusception of alimentary matters, and their assimilation by digestion and respiration; the circulation of the humours; nutrition and secretion; the renewal of materials accompanying the exercise of life, and the constant changes of composition in the solid and liquid parts of the organism,—all of which are influenced by the nervous system,—participate in the evolution of heat, and we deceive ourselves, when we look for the cause in one of those acts only. In certain experiments by Dr. Robert E. Rogers,[4] then of the University of Virginia, he found that when recently drawn venous blood, contained in a freshly removed pig's bladder, was immersed in oxygen gas, there was a remarkable elevation of temperature. Dr. Davy[5] performed experiments which led to the same results. In one of these, he took a very thin vial, of the capacity of eight fluidounces, and carefully enveloped it in badly conducting substances,—for example, in several

[1] Van Swieten, Comment. in Boerhaav. Aphorism., &c., §§ 382, 675, Lugd. Bat., 1742–1772.

[2] On Animal Heat, p. 47, Lond., 1747.

[3] Traité de Physiologie, &c., trad. par. Jourdan, p. 514, Paris, 1831.

[4] Amer. Journal of the Med. Sciences, p. 297, for Aug., 1836.

[5] Proceedings of the Royal Society for 1837–8, No. 34; and Researches Physiological and Anatomical, American Med. Lib. edit., p. 89, Philad., 1840.

folds of flannel, fine oiled paper, and oiled cloth. Thus prepared, and a perforated cork being provided holding a delicate thermometer, two cubic inches of mercury were introduced, and immediately after it was filled with venous blood kept liquid by agitation. The vial was then corked, and shaken. The thermometer included was stationary at 45°. After five minutes, during which it remained so, it was withdrawn; the vial, closed by another cork, was transferred inverted to a mercurial bath, and 1½ cubic inch of oxygen introduced. The common cork was returned, and the vial was well agitated for about a minute; the thermometer was now introduced; it rose immediately to 46°, and by continuing the agitation, to 46·5°, and very nearly 47°. This experiment was made on the blood of the sheep. These, and other experiments of a similar character, Dr. Davy thinks, appear to favour the idea, that animal heat is owing, first, to the fixation or condensation of oxygen in the blood of the lungs in its conversion from venous to arterial; and secondly, to the combinations into which it enters in the circulation in connexion with the different secretions and changes essential to animal life.

Subsequent experiments by M. Chossat[1] confirm the view of the great dependence of calorification on the proper supply of materials on which changes have to be effected in the system of nutrition. He found, that birds, totally deprived of food and drink, experienced a gradual, although slight daily diminution of temperature. This was not shown so much by a fall of their maximum heat, as by an increase in the diurnal variation which existed in the healthy state. The amount of this variation in birds properly supplied with food is 1½° of Fahrenheit daily—the maximum being about noon, and the minimum at midnight. In the state of inanition, however, the average variation was about 6°, and it increased as the animal became weaker. The gradual rise of temperature, too, which should have taken place between midnight and noon, was retarded; whilst the fall subsequent to noon commenced much earlier than in the healthy state; so that the average of the whole day was lowered by about 4½° between the first and last day but one of this condition. On the last day, the diminution took place very rapidly, and the thermometer fell from hour to hour, until death supervened—the whole loss on that day being about 25° Fahrenheit, making the total depression about 29½°. On examining the amount of loss sustained by the different organs of the body, it was found that 93 per cent. of the fat had disappeared,—all, in fact, that could be removed; whilst the nervous centres exhibited scarcely any diminution in weight. The loss in the weight of the whole body averaged about 40 per cent. This preservation of weight on the part of the nervous centres has been regarded, but with little plausibility, to favour the idea, that they may be formed from fatty matter,[2]—a portion of the fat absorbed being appropriated for their nutrition; yet it would be strange, if proteinaceous compounds should be required for other organized structures, and the highest of all in

[1] Recherches Expérimentales sur l'Inanition, Paris, 1843; noticed in Brit. and For. Med. Rev., April, 1844.

[2] Carpenter, Principles of Human Physiology, 2d edit., p. 675, London, 1844.

importance should originate from a non-nitrogenized material, or what Liebig terms an "element of respiration." Dr. Carpenter,—in commenting on the experiments of Chossat,—remarks, that from the constant coincidence between the entire consumption of the fat, and the depression of temperature, joined to the fact that the duration of life under the inanitiating process evidently varied *cæteris paribus* with the amount of fat previously accumulated in the body, the inference seems irresistible, that the calorifying power depended chiefly—if not wholly—on the materials supplied by this substance; and he adds—whenever the store of combustible matter in the system was exhausted, whether by the respiratory process alone, or by this in conjunction with the conversion of adipous matter into the materials for the nervous or other tissues, the inanitiated animals died by the cooling of their bodies consequent upon the loss of calorifying power. This is plausible; yet it can be readily imagined, that the loss of the accustomed supply of aliment may so interfere with changes perpetually taking place in the system of nutrition, as to give occasion to the functional changes, which eventuate in the loss of life, and that the system cannot exist for any length of time on the materials that are taken up from itself. The use of the fat as a nutriment deposited for special occasions is generally admitted by physiologists. Its use as an element of respiration has only been suggested of late years; and it must be admitted, that the view which has been embraced by Dr. Carpenter is somewhat supported by the experiments of M. Chossat, who found that if inanitiated animals, when death is impending, were subjected to artificial heat, they were almost uniformly restored from a state of insensibility and want of muscular power to a condition of comparative activity; their temperature rose; muscular power returned; they flew about the room and took food when it was presented to them; and if the artificial assistance was sufficiently prolonged, and they were not again subjected to the starving process, most of them recovered. In other words, it might be said, that the application of artificial warmth prevented the farther consumption of the fuel—fat—and exerted a most salutary agency on the organic as well as the animal functions.

The experiments of M. Chossat are the more worthy of attention and of careful repetition, from their seeming to lead to a conclusion, which, Dr. Carpenter thinks, can scarcely be questioned, from the similarity of the phenomena,—that inanitiation with its consequent depression of temperature is the immediate cause of death in various diseases of exhaustion. Hence it has been suggested, that in those forms of febrile maladies in which no decided lesion is discoverable after death, a judicious and timely application of artificial heat might prolong life until the malignant influence—as in cases of narcotic poisoning—had passed away. It has been suggested, too, that the beneficial result of alcohol in protracted cases of such fevers, and the large amount in which it may be given with impunity, may probably be accounted for on this principle. "We cannot support the system in fever by *aliment*, for this would not be digested, even if it were taken into the stomach. But we well know the beneficial effects of alcohol in its advanced stages; and the large quantity of this stimulus that may be administered in many cases of fever is a matter of familiar experience. Now, admitting that its beneficial operation is partly due to its specific effect upon the nervous system, we cannot help thinking, that we are to regard it as also resulting from the new supply of combustible material, which is thus introduced in the only form in which it can be taken up by the vascular system. If we turn our attention for a moment to the state of the digestive apparatus at this period, we shall at once see why no other substance should answer the same purpose. In the advanced stage of fever, the secretion of gastric fluid, and the special absorbent process which takes place through the villi and lacteals, seem to be in complete abeyance. Still, however, simple imbibition may go on through the walls of the bloodvessels, provided the circumstances are favourable to the production of endosmose; that is, provided the fluid in the alimentary canal is less dense than the blood. Now, the substances on which we ordinarily depend for the support of the respiratory process are either of an oily, a saccharine, or a mucilaginous character. Oily substances cannot be taken in by imbibition, since they completely check the endosmotic current. Saccharine and mucilaginous substances can only be taken in, when their solution is so dilute as to be of a density much inferior to that of the blood; hence they must be given in a large bulk of fluid; a practice of which experience has shown the benefit. But alcohol, being already of a density far inferior to that of the blood, is easily absorbed; and, from deficiency of other materials, it is rapidly consumed, so that a very large quantity may be thus ingested, without its stimulating effects being perceptible; just as we see that, in a very cold atmosphere, large quantities of spirituous liquors may be taken with impunity, on account of the rapid combustion they undergo."[1]

It is by the theory of the general evolution of caloric in the tissues or in the system of nutrition, that we are able to account for the increased heat that occurs in certain local affections, in which the temperature greatly exceeds that of the same parts in health. By some, it has been doubted, whether, in local inflammation, any such augmentation of temperature exists; but the error seems to have arisen from the temperature of the part in health having been generally ranked at blood heat; whereas it differs essentially in different parts. Dr. Thomson found, that a small inflamed spot in his right groin gave out, in the course of four days, a quantity of heat sufficient to have heated seven wine-pints of water from 40° to 212°; yet the temperature was not sensibly less than that of the rest of the body at the end of the experiment, when the inflammation had ceased.[2] By supposing, too, that calorification is effected in every part of the body, we can understand why different portions should have different temperatures; as the activity of the function may vary, in this respect, according to the organ. MM. Chopart and Dessault found the heat of the rectum 100°; of the axilla and groin, when covered with clothes, 96°; and of the chest, 92°. Dr. Davy[3] found the temperature of a naked man, just risen from bed, to be 90° in the middle of the sole of the foot; 93° between the inner ankle and tendo achillis; 91·5° in the middle of the

[1] Brit. and For. Med. Rev., April, 1844, p. 356.
[2] Annals of Philosophy, ii. 27.
[3] Philosoph. Transact. for 1814.

shin; 93° in the calf; 95° in the ham; 91° in the middle of the thigh; 96·5° in the fold of the groin; 95° at three lines beneath the umbilicus; 94° on the sixth rib of the left side; 93° on the same rib of the right side; and 98° in the axilla. MM. Edwards and Gentil found the temperature of a strong adult male in the rectum and mouth, 102°; in the hands, 100°; in the axilla and groins, 98°; on the cheeks, 97°; on the prepuce and feet, 96°; and on the chest and abdomen, 95°. It is obvious, however, that all these experiments concern only the temperature of parts which can be readily modified by the circumambient medium. To judge of the comparative temperature of the internal organs, Dr. Davy killed a calf, and noted that of different parts, both external and internal. The blood of the jugular vein raised the thermometer to 105·5°; that of the carotid artery to 107°. The heat of the rectum was 105·5°; of the metatarsus, 97°; of the tarsus, 90°; of the knee, 102°; of the head of the femur, 103°; of the groin, 104°; of the under part of the liver, 106°; of the substance of that organ, 106°; of the lung, 106·5°; of the left ventricle, 107°; of the right, 106°; and of the substance of the brain, 104°. M. Chevallier[1] investigated the temperature of the urine on issuing from the bladder. He found it to be affected by rest, fatigue, change of regimen, remaining in bed, &c. The lowest temperature, which was observed on rising in the morning, was about 92°; the highest, after dinner and when fatigued, 99°. In the case of another person, the temperature of the fluid was never lower than 101°; and occasionally, when he was fatigued, it was upwards of 102°. By M. Brown-Séquard,[2] its mean temperature in man was observed to be 102·6°; and he rates that of the thoracic and abdominal viscera, in the human species, in both sexes, between 102° and 103°. Berger, and Maunoir, and himself, found the temperature of the rectum in healthy persons between 100° and 102° of Fahrenheit. In the case of fistulous opening into the stomach, observed by Dr. Beaumont,[3] the thermometer indicated a difference of three-fourths of a degree between the heat of the splenic and pyloric orifices of the stomach; the temperature of the latter being more elevated.

Some interesting observations have been made in this direction by MM. Bernard and Walferdin, the results of which were communicated to M. Gavarret.[4] It has been already remarked, that the blood of the right side of the heart is hotter than that of the left. It was found, moreover, that the blood in the superior vena cava, and of all the veins opening into it, was constantly cooler than that of the arch of the aorta, and of the arteries sent off from it at the same distance from the heart. The results were more complex, as regarded the vena cava ascendens, and the descending aorta, and their branches. Thus, the blood of the renal vein was warmer than that of the renal artery; that of the vena porta, before its entrance into the liver, was of less temperature than that of the supra-hepatic veins; that of the supra-hepatic veins warmer than that of the aorta immediately below the diaphragm, and that of

[1] Essai sur la Dissolution de la Gravelle, &c., p. 120, Paris, 1837.
[2] Medical Examiner, Sept., 1852, p. 556.
[3] Exp. and Observations on the Gastric Juice, p. 274, Plattsburg, 1833.
[4] De la Chaleur Produite par les Etres Vivants, p. 109, Paris, 1855.

the lower limbs less than that of the corresponding arteries. The same was the case with the blood of the iliac veins and arteries; that of the vena cava ascendens as far as the entrance of the renal vein was also of less temperature than that of the descending aorta below the origin of the renal arteries. The mixture of the blood of the renal vein with that returning from the lower limbs has this result, that in the vena cava comprised between the mouth of the renal vein and the liver, the blood is warmer than in the portion of the descending aorta, which extends from the diaphragm to the origin of the renal arteries; and lastly, at the point where the supra-hepatic veins disgorge their blood into the vena cava ascendens, the temperature of the blood in the last vein again rises and passes much above that of the blood of the corresponding part of the aorta. The confluence of the supra-hepatic veins and the vena cava is the *warmest place* in the economy. The blood, at least, has there the maximum of observed temperature.

It is not easy to account for these differences, without supposing, that each part has the power of disengaging its own heat, and that the communication of caloric from one part to another is not sufficiently ready to prevent the difference from being perceptible.

Of the mode in which heat is evolved in the system of nutrition, it is impossible for us to arrive at any satisfactory information. The result alone indicates, that the process has been accomplished. In the present state of our knowledge, we are compelled to refer it to some chemico-vital action, of the nature of which we are ignorant; but which seems to be possessed by all organized bodies,—vegetable as well as animal. We know that wherever carbon unites with oxygen to form carbonic acid; oxygen with hydrogen to form water; or with phosphorus or sulphur to form phosphoric acid, and sulphuric acid, as is constantly the case in organized bodies, heat must be disengaged.[1] We shall have to refer hereafter, when treating of the phenomena of DEATH, to interesting observations of Dr. Dowler of New Orleans, and others, showing, that the heat of the body may rise after somatic death,—that is, after the cessation of circulation and respiration; and that the elevation of temperature varies materially in different parts of the body. The disengagement of caloric, which takes place until the supervention of the putrefactive process, must manifestly be of a physical character, and of course in no respect connected with respiration. Still, it may admit of a question, whether it be identical with that which takes place in the living body, and constitutes the function now under consideration. This much, however, the observations establish, that physical changes in the recently dead may give occasion to the evolution of heat in a manner strikingly analogous to what takes place during life.[2]

It was stated early in this chapter, that man possesses the power of resisting cold as well as heat within certain limits, and of preserving his temperature greatly unmodified. A few remarks are needed in regard to the direct and indirect agents of these counteracting influences.

[1] Lehmann, Handbuch der physiologischen Chemie, S. 295, Leipzig, 1854.

[2] See, on the whole subject of the causes of the production of heat in organized beings, Gavarret, De la Chaleur produite par les Etres Vivants, pp. 141 and 529, Paris, 1855.

As the mean temperature of the warmest regions does not exceed 85° of Fahrenheit, it is obvious that he must be constantly giving off caloric to the surrounding medium;—still, his temperature remains the same. This is effected by the mysterious agency which we have been considering, materially aided, however, by several circumstances, both intrinsic and extrinsic. The external envelope of the body is a bad conductor of caloric, and therefore protects the internal organs, to a certain extent, from the sudden influence of excessive heat or cold. But the cutaneous system of man is a much less efficient protection than that of animals. In the warm-blooded, in general, the bodies are covered with hair or feathers. The whale is destitute of hair; but, besides the protection which is afforded by the extraordinary thickness of the skin, and the stratum of fat—a bad conductor of caloric—with which the skin is lined, as the animal constantly resides in the water, it is not subjected to the same vicissitudes of temperature as land animals. Seals, bears, and walruses, which seek their food in the colder seas, sleep on land. They have a coating of hair to protect them. In the case of certain of the birds of the genus *Anas*, of northern regions, we meet with a singular anomaly,—the whole of the circumference of the anus being devoid of feathers; but, to make amends for this deficiency, the animal has the power of secreting an oleaginous substance, with which the surface is kept constantly smeared. It may be remarked, that we do not find the quantity of feathers on the bodies of birds to be proportionate to the cold of the climates in which they reside, as is pretty universally the case regarding the quantity of hair on the mammalia.

Man is compelled to have recourse to clothing for the purpose of preventing the sudden abstraction or reception of heat. This he does by covering himself with substances that are bad conductors of caloric, and retain an atmosphere next to the surface, which is warmed by the caloric of the body. He is compelled, also, in the colder seasons, to have recourse to artificial temperature; and it will be obvious, from what has been said, that the greater the degree of activity of any organ or set of organs, the greater will be the heat developed: and in this way muscular exertion and digestion must influence its production. By an attention to all these points, and by his acquaintance with the physical laws relative to the developement and propagation of caloric, man is enabled to live amongst the Arctic snows, as well as in climates where the temperature is frequently, for a length of time, upwards of 150° lower than that of his own body. The contrivances adopted in the polar voyages, under the various discoverers, are monuments of ingenuity directed to obviate one of the greatest obstacles to prolonged existence in cold inhospitable regions, for which man is naturally incapacitated, and for which he attains the capability solely by the exercise of that superior intellect with which he has been vested by the Author of his being. In periods of intense cold, the extreme parts of the body, unless carefully protected, do not possess the necessary degree of vital action to resist congelation. In the disastrous expedition of Napoleon to Russia, the loss of the nose and ears was a common casualty; and, in Arctic voyages, frost-bites occur in spite of every care.[1] When the temperature of the whole body sinks to about 78° or 79°, death takes place, preceded by the symptoms of nervous depression, which have been previously detailed.

The counteracting influence exerted, when the body is exposed to a temperature greatly above the ordinary standard of the animal, is as difficult of appreciation as that by which calorification is effected. The probability is, that in such case the disengagement of heat is suspended; and that the body receives it from without by direct, but not by rapid, communication, owing to its being an imperfect conductor of caloric. Through the agency of this extraneous heat, the temperature rises a limited number of degrees; but its elevation is generally considered to be checked by the evaporation constantly taking place through the cutaneous and pulmonary transpirations. For this last idea we are indebted to Dr. Franklin,[2] and its correctness and truth have been maintained by most observers. MM. Berger and Delaroche put into an oven, heated to from 120° to 140°, a frog, and one of those porous vessels called *alcarazas*—which permit the transudation of the fluid within them through their sides—filled with water at the temperature of the animal, and two sponges, imbibed with the same water. The temperature of the frog at the expiration of two hours, was 99°; and the other bodies continued at the same. Having substituted a rabbit for the frog, the result was identical. On the other hand, having placed animals in a warm atmosphere, so saturated with humidity that no evaporation could occur, they received the caloric by communication, and their temperature rose; whilst inert, evaporable bodies, put into a dry stove, became but slightly warmed; —much less so, indeed, than the warm-blooded animals in the moist stove. Hence, they concluded, that evaporation is a great refrigerative agent when the body is exposed to excessive heat; and that such evaporation is considerable is shown by the loss in weight which animals sustain by the experiment. It has been contested, however, that the cutaneous evaporation has any effect in tempering the heat of the body. MM. Becquerel and Breschet[3] found, when the hair of rabbits had been shaved off, and the skin covered with an impermeable coating of strong glue, suet, and resin, that the animals died soon afterwards; and, they thought, by a process of asphyxia in consequence of the transpiration from the skin being prevented. In these experiments, to their surprise, the temperature of the animals, instead of rising, fell considerably. Thus, the temperature of the first rabbit, before it was shaved and covered with the impermeable coating, was 38° Centigrade; but immediately after the coating was dry, the temperature of the muscles of the thigh and breast had fallen to 24·5° Centigrade. In another rabbit, on which the coating was put on with more care,—as soon as it was dried, the temperature was found to have fallen so much that it was only three degrees above that of the surrounding atmosphere, which was, on that day, 17° Centigrade. An hour after the animal died. These experiments—and they have been

[1] Larrey, Mémoires de Chirurgie Militaire et Campagnes, tom. iv. p. 91, 106, and 123, Paris, 1817.
[2] Works, iii. 294, Philad., 1809; or Sparks's edit., vi. 213, Boston, 1838.
[3] Comptes Rendus, Oct., 1841.

repeated with like results by M. Magendie[1]—clearly exhibit the importance of the functions executed by the skin. Dr. Carpenter[2] thinks they place in a very striking point of view the importance of the cutaneous surface as a respiratory organ, and enable us to understand how, when the aerating power of the lungs is nearly destroyed by disease, the heat of the body is kept up to its natural standard by the action of the skin. "A valuable therapeutical indication, also," he adds, "is derivable from the knowledge which we thus gain of the importance of the cutaneous respiration; for it leads us to perceive the desirableness of keeping the skin moist in those febrile diseases in which there is great heat and dryness of the surface, since aeration cannot properly take place through a dry membrane." It has been already shown,[3] that local derangement of the apparatus engaged in the important functions of nutrition, calorification and secretion, is the cause of many affections which have been ascribed to a fancied check to perspiration in the part.

M. Edwards, in his experiments on the influence of physical agents on life, observed, that warm-blooded animals have less power of producing heat, after they have been exposed for some time to an elevated temperature, as in summer; whilst the opposite effect occurs in winter. He instituted a series of experiments, which consisted in exposing birds to the influence of a freezing mixture, first in February, and afterwards in July and August; observing in what degree they were cooled by remaining in this situation for equal lengths of time; the result was, that the same kind of animal was cooled six or eight times as much in the summer as in the winter months. This principle he presumes to be of great importance in maintaining the regularity of the temperature at different seasons; even more so than evaporation, the effect of which, in this respect, he thinks, has been greatly exaggerated. From several experiments on yellow hammers, made at different periods in the course of the year, it would result, that the averages of their temperature ranged progressively upwards from the depth of winter to the height of summer, within the limits of five or six degrees of Fahrenheit; and the contrary was observed in the fall of the year. Hence, M. Edwards infers, and with probability, that the temperature of man experiences a similar fluctuation.[4]

When exposed to high atmospheric temperature, the ingenuity of man has to be as much exerted as under opposite circumstances. The clothing must be duly regulated according to physical principles,[5] and perfect quietude be observed, so that undue activity of any of the organs, that materially influence the disengagement of animal heat, may be prevented. It is only within limits, that this refrigerating action is sufficient. At a certain degree, the transpiration is inadequate; the temperature of the animal rises, and death supervenes.

[1] Gazette Médicale de Paris, 6 Déc., 1843.
[2] Principles of Human Physiology, Amer. edit., p. 414, Philad., 1855.
[3] Page 520.
[4] De l'Influence des Agens Physiques, p. 489; and Hodgkin's and Fisher's translation, Lond., 1832.
[5] See the chapter on Clothing in the author's Human Health, p. 340, Philadelphia, 1844.

BOOK II.

ANIMAL FUNCTIONS.

The animal functions or functions of relation comprise sensibility, and muscular motion, including expression or language. Those that are executed with consciousness are subject to intermission, constituting *sleep;* a condition which has, consequently, by many physiologists, been investigated under this class; but as the functions of reproduction are influenced by the same condition, the consideration of sleep will be deferred until the third class of functions has received attention.

The animal functions—as the name imports—are characteristic of the animal; and must, consequently, be accomplished by parts that appertain to it alone. They are all—in other words—attributes of a nervous system,—nothing identical with innervation existing in the vegetable.

CHAPTER I.

SENSIBILITY.

Sensibility, in its general acceptation, means the property possessed by living parts of receiving impressions, whether the being exercising it has consciousness or not. To the first of the cases—in which there is consciousness—Bichat gave the epithet *animal;* to the second, *organic;* the latter being common to animals and vegetables, and presiding over the *organic* functions of nutrition, absorption, exhalation, secretion, &c.; the former existing only in animals, and presiding over the sensations, internal as well as external, and the intellectual and moral manifestations.

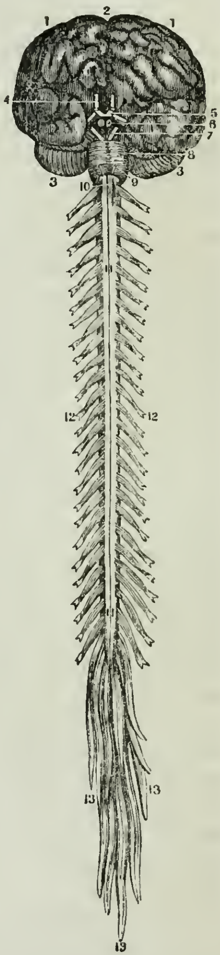
Pursuing the plan already laid down, the study of this interesting and elevated function will be commenced, by pointing out, as far as may be necessary, the apparatus that effects it, the *nervous system.*

1. NERVOUS SYSTEM.

Under the name *nervous system*, anatomists include all those organs that are composed of nervous or pulpy tissue—neurine. In man, it is constituted of three portions: *first*, of what has been called the *cerebro-spinal* or *cranio-spinal axis*, a central part having the form of a long cord, expanded at its superior extremity, and contained within the cavities of the cranium and spine; *secondly*, of cords, called *nerves*, in number thirty-nine pairs, according to some,—forty-two, according to others,—passing laterally between the cerebro-spinal axis and every part of the body; and, lastly, of a nervous cord, situate on each side of the spine, from the head to the pelvis, forming *ganglia* opposite each vertebral foramen, and called the *great sympathetic.*

1. *Encephalon.*—Under this term are included the contents of the cranium,—namely, the *cerebrum* or *brain proper*, the *cerebellum* or *little brain*, and the *medulla oblongata*. These parts collectively have been by some called *brain*.

Fig. 184.



Anterior view of the Cerebro-Spinal Axis.

1, 1. Hemispheres of the cerebrum. 2. Great middle fissure. 3. Cerebrum. 4. Olfactory nerves. 5. Optic nerves. 6. Corpora albicantia. 7. Motor oculi nerves. 8. Pons Varolii. 9. Fourth pair of nerves. 10. Lower portion of medulla oblongata. 11, 11. Medulla spinalis. 12, 12. Spinal nerves. 13. Cauda equina.

When we look at a section of the encephalon, in its natural position, we find many distinct parts, and the appearances of numerous and separate organs. So various, indeed, are the prominences and depressions observable on the dissection of the brain, that it is generally esteemed one of the most difficult subjects of anatomy; yet, owing to the attention paid to it in all ages, it is now one of the structures best understood by the anatomist. This complicated organ presents a striking illustration of the truth, that the most accurate anatomical knowledge does not necessarily teach the function. The elevated actions, which the encephalon has to execute, have, indeed, attracted a large share of the attention of the physiologist,—too often, however, without any satisfactory result; yet it may, we think, be safely asserted, that we have become better instructed regarding the uses of particular parts of the brain, within the last few years, than during the whole of the century preceding.

The encephalon being of extremely delicate organization, and its functions easily deranged, it was necessary that it should be securely lodged and protected from injuries. Accordingly, it is placed in a round, bony case; and by an admirable mechanism is defended against damage from surrounding bodies. Amongst these guardian agents or *tutamina cerebri* must be reckoned;—the hair of the head; the skin; muscles; pericranium; bones of the skull; the diploë separating the two tables of which the bones are composed, and the dura mater.

It is not an easy matter to assign probable uses for the hair on various parts of the body. On the head, its function seems more readily appropriable. It deadens the concussion, which the brain would experience from the infliction of heavy blows, and prevents the skin of the scalp from being injured by the attrition of bodies. In military service, the former of these uses has been taken advantage of; and an arrangement, somewhat similar to that which exists naturally on the head, has been adopted with regard to the helmet. The metallic substance, of which the ancient and modern helmets are formed, is readily thrown into vibration; and this vibration being communicated to the brain might, after heavy blows, derange its functions more even than a wound inflicted by a sharp instrument. To obviate this, in some measure, the helmet has been covered with horse-hair; an arrangement which existed in the helmet worn by the Roman soldier. There can be no doubt, moreover, that being bad conductors of caloric, and forming a kind of felt which intercepts the air, the hairs may tend to preserve the head of a more uniform temperature. They are likewise covered with an oily matter, which prevents them from imbibing moisture, and causes them to dry speedily. Another use ascribed to them by M. Magendie,[1] is more hypothetical;—that, being bad conductors of electricity, they may put the head in a state of insulation, so that the brain may be less affected by the electric fluid.

It is unnecessary to explain in detail the different layers of which the scalp is composed. The areolar membrane beneath; the panniculus carnosus or occipito-frontalis muscle; and the pericranium covering the bone, act the parts of tutamina. The most important of these protectors is the bony case itself. In an essay written by a distinguished physiologist,[2] we have some beautiful illustrations of the wisdom of God as displayed in the mechanism of man, and of his skull in particular; and although some of his remarks may be liable to the censures that have been passed upon them by Dr. Arnott,[3] most of them are admirably adapted to the contemplated object. It is impossible, indeed, for the uninitiated to rise from the perusal of his interesting essay, without being ready to exclaim with the poet, "How wonderful, how complicate is man! how passing wonder HE that made him such!" Sir Charles Bell attempts to prove, that the best illustration of the form of the head is the dome; whilst Dr. Arnott considers it to be "the arch of a cask or barrel, egg-shell, or cocoa-nut, &c., in which the tenacity of the material is many times greater than necessary to resist the influence of gravity, and comes in aid, therefore, of the curve to resist forces of other kinds approaching in all directions, as in falls, blows, unequal pressures," &c. The remarks of Dr. Arnott on this subject are just: and it is owing to this form of the cranium, that any blow received upon one part of the skull is rapidly distributed to every other; and that a heavy blow, inflicted on the forehead or vertex, may cause a fracture, not in the parts struck but in the occipital or sphenoidal bone.

The skull does not consist of one bone, but of many. These are joined together by *sutures*,—so called from the bones seeming as if they were *stitched* together. Each bone consists likewise of two tables; an external, fibrous, and tough; and an internal, of a harder character and more brittle, hence called *tabula vitrea*. The two are separated from each other by a cellular or cancellated structure, called *diploë*. On examining the mode in which the tables form a function with each other at the sutures, we find additional evidences of design exhibited. The edges of the outer table are serrated, and so arranged as to be

[1] Précis Elémentaire, edit. cit., i. 177.

[2] Sir Charles Bell, in Animal Mechanics—Library of Useful Knowledge, London, 1829.

[3] Elements of Physics or Natural Philosophy, General and Medical, London, 1827—reprinted in this country, Philad., 1841.

accurately dovetailed into each other; the tough fibrous texture of the external plate being well adapted for such a junction. On the other hand, the tabula vitrea, which, on account of its greater hardness, would be liable to fracture and chip off, is merely united with its fellow at the suture by what is called *harmony;* the tables are merely placed in contact.

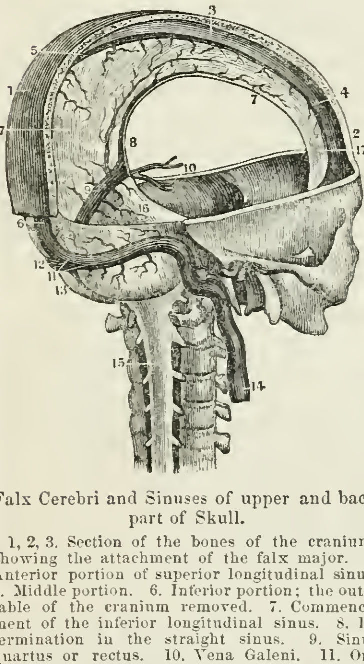
The precise object of the sutures is not apparent. In the mode in which ossification takes place in the bones of the skull, the radii from different ossific points must necessarily meet by the "law of conjugation," in the progress of ossification. This has, by many, been esteemed the cause of the sutures; but the explanation is insufficient. Howsoever it may be, the kind of junction affords a beautiful example of adaptation. During the fœtal state, the sutures do not exist. They are fully formed in youth; are distinct in the adult age; but in after periods of life become entirely obliterated, the bone then forming a solid spheroid. It does not seem that after the sutures are established, any displacement of the bones can take place; and observation has shown, that they do not possess much, if any, effect in putting a limit to fractures. In all cases of severe blows, the skull appears to resist as if it were constituted of one piece. But the separation of the skull into distinct bones, which have a membranous union, is of striking advantage to the fœtus in parturition. It enables the bones to overlap each other; and, in this way, to occupy a much smaller space than if ossification had united them as in after life. It has been imagined by some, that there is an advantage in the pressure made on the brain by the investing bones,—that the fœtus does not suffer from the violent efforts made to extrude it; but, during the passage through the pelvis, is in a state of fortunate insensibility. Pressure suddenly exerted upon the brain is certainly attended with these effects,—a fact, which has to be borne in mind in the management of apoplexy, fracture of the skull, &c.

The uses of the *diploë*, which separates the two tables of the skull, are not equivocal. Composed of a cancellated structure, it is well adapted to deaden the force of blows; and as it forms, at the same time, a bond of union and of separation, a fracture might be inflicted upon the outer table of the skull, and yet be prevented from extending to the tabula vitrea. Such cases have occurred, but they are rare. It will generally happen, that a blow, intended to cause serious bodily injury, will be sufficient to break through both tables, or neither.

Lastly, the *dura mater*, which has been reckoned as one of the tutamina cerebri, lines the skull, and constitutes a kind of internal periosteum to it. It may also be inservient to useful purposes, by deadening the vibrations, into which the head may be thrown by sudden concussions; as the vibrations of a bell are arrested by lining it with a soft material. It is chiefly, however, to protect the brain against itself, that we have the arrangement which prevails. The cerebrum, as well as the cerebellum, consists of two hemispheres; and its posterior part is situate immediately above the cerebellum. It is obvious, then, that without some protection, the hemisphere of one side would press upon its fellow, when the head is inclined to the opposite side; and that the posterior lobes of the brain would weigh upon the cerebellum in the erect attitude.

The *hemispheres* are separated from each other by the *falx cerebri*, in the upper margin of which is the *superior longitudinal sinus*. The falx passes between the hemispheres. The *tentorium cerebello superextensum*—a prolongation of the dura mater—passes horizontally forwards so as to support the posterior lobes of the brain, and prevent them from pressing injuriously on the *cerebellum*. A process of the dura mater passes also between the hemispheres of the cerebellum. Independently of the protection afforded to the encephalon, the dura mater lodges the great sinuses into which the veins discharge their blood. These different sinuses empty themselves into the *torcular Herophili* or *confluence of the sinuses*; and ultimately proceed to constitute the *lateral sinuses*, which pass through the temporal bone, and form the *internal jugular veins*.

Fig. 185.



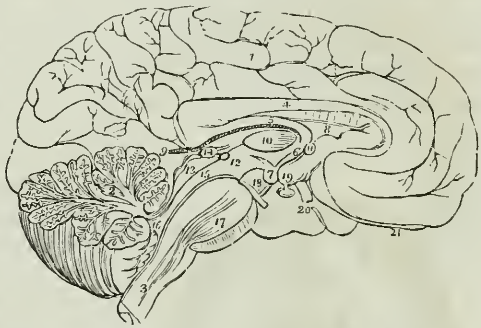
Falx Cerebri and Sinuses of upper and back part of Skull.

1, 2, 3. Section of the bones of the cranium, showing the attachment of the falx major. 4. Anterior portion of superior longitudinal sinus. 5. Middle portion. 6. Inferior portion; the outer table of the cranium removed. 7. Commencement of the inferior longitudinal sinus. 8. Its termination in the straight sinus. 9. Sinus quartus or rectus. 10. Vena Galeni. 11. One of the lateral sinuses. 12. Torcular Herophili. 13. Sinus of the falx cerebelli. 14. Internal jugular vein. 15. Dura mater of the spinal marrow. 16. Tentorium cerebelli. 17, 17. Falx cerebri.

The tutamina are not confined to the contents of the cranium. The spine appears to be, if possible, still better protected. In the skull, we see a firm, bony case; in the spine, a structure admitting considerable motion of the parts, without risk of pressure to the marrow. Accordingly, the spine consists of numerous distinct bones or vertebræ, with fibro-cartilaginous—technically called *intervertebral*—substances placed between each, so that, although the extent of motion between any two of these bones may be small, when all are concerned, it is considerable. The great use of this intervertebral substance is to prevent the jar, that would necessarily be communicated to the delicate parts within the cavities of the spine and cranium, were the spine composed entirely of one bone. In falls from a height upon the feet or breech, these elastic cushions are forcibly compressed; but they immediately return to their former condition, and deaden the force of the shock. In this they are aided by the curvatures of the spine, which give it the shape of the Italic *ſ*, and enable it to resist—in the same manner as a steel spring—any force acting upon it in a longitudinal direction. So well is the medulla spinalis protected by the strong bony processes jutting out in various directions from the spine, that it is extremely rare to meet with lesions of the marrow; and it is comparatively in recent periods that any *ex professo* treatises have appeared on the subject.

Besides the protection afforded by the bony structure to the delicate medulla, M. Magendie has pointed out another, which he was the first to detect. The canal, formed by the dura mater around the spinal cord, is much larger than is necessary to contain that organ; but, during life, the whole of the intermediate space is filled with a serous fluid, which strongly distends the membrane, so that it will frequently spirt out to a distance of several inches, when a puncture is made in the membrane. To this fluid he has given the epithet *cephalo-spinal;* and he conceives, that it may act as one of the tutamina of the marrow—which is, as it were, suspended in the fluid—and exert upon it the pressure necessary for the healthy performance of its functions.

Fig. 186.

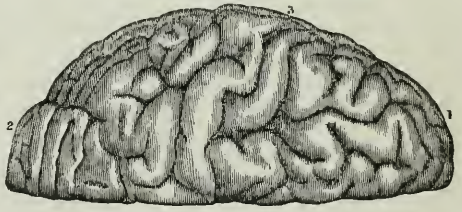


Longitudinal Section of the Brain on the Mesial Line.

1. Inner surface of the left hemisphere. 2. Divided surface of the cerebellum, showing the arbor vitæ. 3. Medulla oblongata. 4. Corpus callosum, continuous with 5, the fornix. 6. One of the crura of the fornix descending to 7, one of the corpora albicantia. 8. Septum lucidum. 9. Velum interpositum, communicating with the pia mater of the convolutions through the fissure of Bichat. 10. Section of the middle commissure in the third ventricle. 11. Section of the anterior commissure. 12. Section of the posterior commissure; the commissure is somewhat above and to the left of the number. The interspace between 10 and 11 is the foramen commune anterius, in which the crus of the fornix (6) is situate. The interspace between 10 and 12 is the foramen commune posterius. 13. Corpora quadrigemina, upon which is the pineal gland, 14. 15. Iter à tertio ad quartum ventriculum. 16. Fourth ventricle. 17. Pons Varolii, through which are passing the diverging fibres of the corpora pyramidalia. 18. Crus cerebri of the left side, with the third nerve arising from it. 19. Tuber cinereum, from which projects the infundibulum having the pituitary gland appended to its extremity. 20. One of the optic nerves. 21. Left olfactory nerve.

Beneath the dura mater is a very delicate membrane, the *arachnoid*, belonging to the class of serous membranes. It surrounds the encephalon in every part; but is best seen at the base of the brain. Its chief use is to secrete a thin fluid, to lubricate the brain. This membrane enters into all the cavities of the organ, and in them fulfils a like function. When the fluid accumulates to a great extent, the resulting disease is *hydrocephalus chronicus*. Henle has shown that it is not a serous sac, like the pleura or pericardium. Its inner surface, according to Kölliker,[1] with its epithelium, is everywhere in close contact with the dura mater, so that a *cavum arachnoideæ* does not exist.

Fig. 187.



Convolutions of one Side of the Cerebrum as seen from above.

1. Anterior lobe of the cerebrum. 2. Posterior lobe. 3. Middle lobe.

Anatomists usually describe a third tunic of the brain—the *pia mater*. This is generally conceived to consist of the minute termi-

[1] Mikroskopische Anatomie, Bd. ii. S. 491, Leipz., 1850; and Amer. edit. of Sydenham Society's edition of his Human Histology, by Dr. Da Costa, p. 395, Philad., 1854. See, also, Jones and Sieveking, Manual of Pathological Anatomy, Amer. edit., p. 231, Philad., 1854.

nations of the cerebral arteries, and those of the corresponding veins; forming at the surface of the brain a vascular network, which passes into the cavities; and, in the ventricles, forms the *plexus choroides* and *tela choroidea*. The dura and pia mater were so called by the older anatomists, because they were conceived to be the origin of all the other membranes of the body.

The *cerebrum* or *brain proper* has the form of an oval, larger behind. On its outer surface are various undulating eminences, called *convolutions*, because they have been thought to resemble the folds of the intestines. They are separated from each other by depressions called *anfractuosities*. They form the *hemispherical ganglion* of Mr. Solly. In the brain of man, these convolutions are larger than in animals; and the anfractuosities deeper. In different brains, the number, size, and arrangement of these vary. They are not the same, indeed, in the same individual; those of the right hemisphere being disposed differently from those of the left.

Fig. 188.

Superior Part of the Lateral Ventricles, Corpora Striata, Septum Lucidum, Fornix, &c., as given by a Transverse Section of the Cerebrum.

1. Section of the os frontis. 2. Section of the os occipitis. 3. Section of the ossa parietalia. 4, 5. Anterior and posterior extremities of the middle fissure of the cerebrum. 6. Anterior extremity of the corpus callosum. 7. Its posterior extremity joining the fornix. 8, 8. Point to where the corpus callosum joins the lateral medullary matter of the cerebrum. 9. Its place of junction anteriorly. 10. Posterior point of union. 11. Middle portion of the corpora striata (lateral ventricle). 12. Tænia striata. 13. Septum lucidum. 14. Fifth ventricle. 15. Fornix. 16. Posterior crura. 17. Plexus choroides. 18. Ergot or hippocampus minor. 19. Posterior crura of the lateral ventricle.

The hemispheres, it has been seen, are separated *above* by the falx cerebri: *below*, they are united by a white medullary commissure, *corpus callosum*, *mésolobe* or *great commissure*,—*great transverse commissure* of Mr. Solly. If we examine the brain at its base, we find that each hemisphere is divided into three lobes,—an *anterior*, which rests on the vault or roof of the orbit,—a *middle* or *temporal*, filling the middle and lateral parts of the base of the cranium, and separated from the former by a considerable depression, called *fissure of Sylvius*,—and a *posterior*, which rests on the tentorium cerebelli. This part of the cerebrum is divided into two very distinct portions by the medulla oblongata. Anterior to it are the *crura cerebri* or *cerebral peduncles*—by most anatomists considered to be a continuation of the anterior fasciculi which form the spinal marrow and medulla oblongata, and proceeding to form the hemispheres of the brain. Between the anterior extremities of the peduncles are two hemispherical projections, called *eminentiæ mammillares*, which are possessed by man exclusively; have the shape of a pea; and are formed of white nervous tissue externally, of gray within. Anterior to these again is the *infundibulum;* and a little farther forwards, the *chiasma* of the optic nerves or the part at which these nerves come in contact.

Laterally, and at the inferior surface of the anterior lobes, is a groove or furrow, running from behind to before, and from without to within, in which the *olfactory nerve* is lodged. At the extremity of this furrow is a tubercle, which is trifling in man, but in certain animals is equal to the rest of the brain in bulk. From this the olfactory nerve has been conceived to arise. It is called the *olfactory tubercle* or *lobe.*

When we examine the interior of the brain, we find a number of parts to which the anatomist assigns distinct names. Of these the following chiefly concern the physiologist. It has been already remarked, that the corpus callosum forms at once the bond of union and of separation between the two hemispheres. It is distinctly perceived, in the form of a long and broad white band, on separating these parts from each other. Beneath the corpus callosum is the *septum lucidum* or median septum, which passes perpendicularly downwards, and separates from each other the two largest cavities of the brain,—the *lateral ventricles.* It is formed of two laminæ, which leave a cavity between them, called the *fifth ventricle.* The *fornix* or *inferior longitudinal commissure* of Mr. Solly, whose office is to connect the anterior and posterior parts of the same hemisphere, as the transverse commissures do those of the opposite hemisphere, is placed horizontally below the last. The band of fibres which runs in each hemisphere above the corpus callosum, on the edge of the longitudinal fissure, is the *superior longitudinal commissure* of Mr. Solly. Its use is supposed to resemble that ascribed to the inferior longitudinal commissure. The fornix is of a triangular shape; and constitutes the upper paries of another cavity—the third ventricle. Beneath the fornix, and behind, are the *pineal gland* and its peduncles, forming the *pineal commissure* of Mr. Solly, respecting which so much has been said, by Descartes,[1] and others, as the seat of the soul. Within it is a small cavity; and, after six or seven years of age, it always contains some concretions. Again, anterior to the pineal gland, and immediately

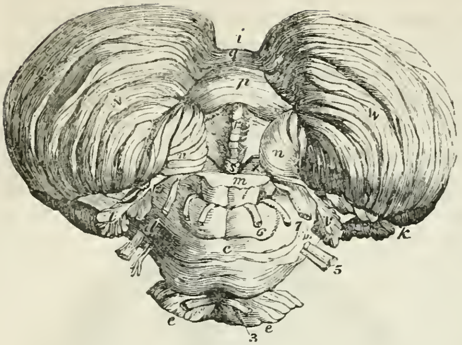
Fig. 189.

Section of the Cerebrum, displaying the surfaces of the Corpora Striata, and Optic Thalami, the cavity of the Third Ventricle, and the upper surface of the Cerebellum.

a, e. Corpora quadrigemina,—*a,* testes; *e,* nates. *b.* Soft commissure. *c.* Corpus callosum. *f.* Anterior pillars of fornix. *g.* Anterior cornu of lateral ventricle. *k, k.* Corpora striata. *l, l.* Optic thalami. *. Anterior tubercle of the left thalamus. *z* to *s.* Third ventricle. In front of *z,* anterior commissure. *b.* Soft commissure. *s.* Posterior commissure. *p.* Pineal gland with its peduncles. *n, n.* Processus à cerebello ad testes. *m, m.* Hemispheres of the cerebellum. *h.* Superior vermiform process. *i.* Notch behind the cerebellum.

[1] Tractatus de Homine, p. 5.

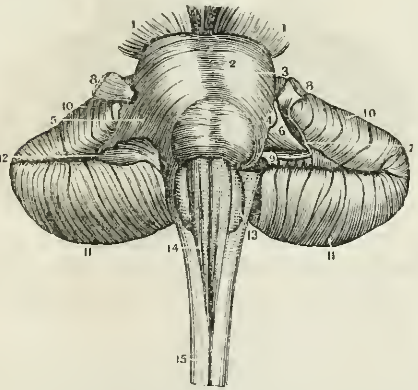
Fig. 190.



An under View of the Cerebellum, seen from behind, the Medulla Oblongata, *m*, having been cut off a short way below the Pons.

c. Pons Varolii. *d*. Middle crus of cerebellum. *e*, *e*. Crura cerebri. *i*. Notch on posterior border. *k*. Commencement of horizontal fissure. *l*. Flocculus, or subpeduncular lobe. *m*. Medulla oblongata cut through. *q* to *s*. The inferior vermiform process, lying in the vallecula. *p*. Pyramid. *r*. Uvula. *n*, *n*. Amygdalæ. *s*. Nodule, or laminated tubercle. *x*. Posterior velum, partly seen. *w*. Right and left hemispheres of cerebellum. 3 to 7. Nerves. 3, 3. Motores oculorum. 5. Trigeminal. 6. Abducent nerve. 7. Facial and auditory nerves.

Fig. 191.



Posterior Superior View of the Pons Varolii, Cerebellum, and Medulla Oblongata and M. Spinalis.

1, 1. Crura cerebri. 2. Pons Varolii or tuber annulare. 3. Its middle fossa. 4. Oblique band of medullary matter seen passing from its side. 5. External surface of the crus cerebelli. 6. Same portion deprived of outer layer. 7. Nervous matter which unites it to 4. 8. Trigeminus or fifth pair of nerves. 9. Portion of the auditory nerve. The white neurine seen passing from the oblique band which comes from the corpus restiforme to the trigeminus nerve in front, and the auditory nerve behind. 10, 11. Superior portion of the hemispheres of the cerebellum. 12. Lobulus amygdaloides. 13. Corpus olivare. 14. Corpus pyramidale. 15. Medulla spinalis.

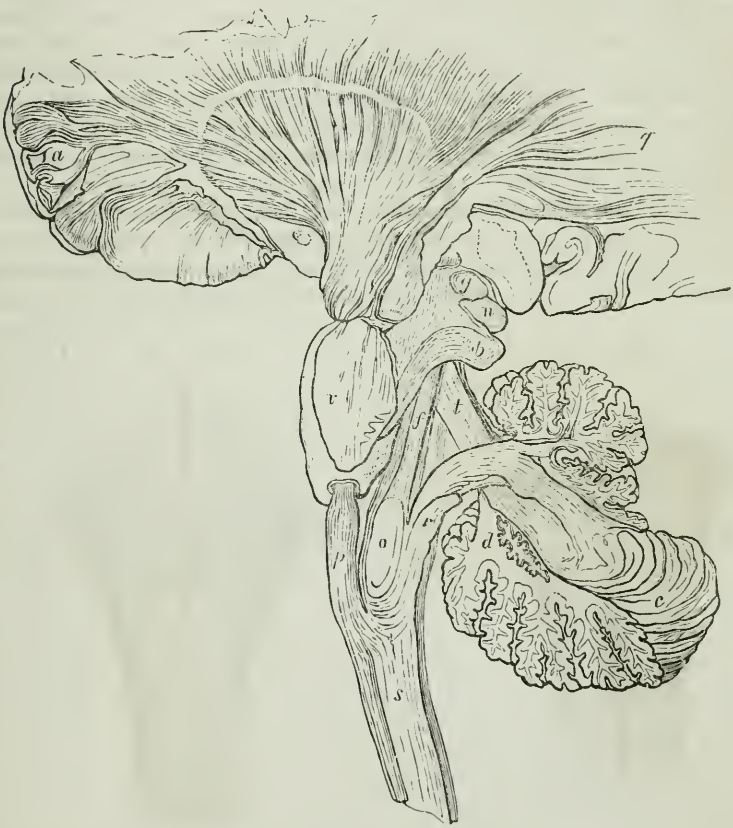
below the fornix, is another cavity—the *third ventricle*. Its bottom is very near the base of the brain, and is formed by the nervous layer which unites the peduncles of the brain with the eminentiæ mammillares. At the sides, it has the thalami nervorum opticorum.

In the lateral ventricles, situate on each side of the corpus callosum, some parts exist which demand attention. In the upper or anterior half, commonly called *anterior cornu*, and in the anterior part of this, two pyriform eminences are seen, of a brownish-gray colour, which, owing to their being formed of an assemblage of alternate layers of white and gray substance, are called *corpora striata*, the *anterior cerebral ganglions* of Mr. Solly. Behind these, are two whitish medullary bodies called *thalami nervorum opticorum*—*posterior cerebral ganglions*—which are situate before the corpora quadrigemina, and envelope the anterior extremities of the crura cerebri.

Three main sets of fibres may be distinguished in the medullary substance, of which the great mass of the cerebrum is composed. *First*, the ascending fibres, which proceed from the sensory tract of the medulla spinalis, and diverge from the thalami optici to the periphery of the brain; *secondly*, the descending fibres, which converge from the periphery towards the corpora striata, and then pass downwards to the motor tract of the medulla spinalis; and, *thirdly*, the commissural fibres, which establish a connexion between the various parts of the periphery, and of the substance of the brain. The bulk of the human brain, and of that of the higher animals, is greatly dependent upon the large proportion borne by these last fibres to the rest.[1]

The *cerebellum* occupies the lower occipital fossæ, or the whole of the cavity of the cranium beneath the tentorium cerebelli. It consists of two lateral hemispheres or lobes, composed of a peculiar arrangement of vesicular and tubular substance; and of a central lobe, composed also of these substances, and known by the name of the *worm* or *vermiform process.* Its size and weight, like those of the brain, differ according to the individual, and the age of the subject under examination. We do

Fig. 192.



Analytical Diagram of the Encephalon—in a Vertical Section.

s. Spinal cord. *r.* Restiform bodies passing to *c*, the cerebellum. *d.* Corpus dentatum of the cerebellum. *o.* Olivary body. *f.* Columns continuous with the olivary bodies and central part of the medulla oblongata, and ascending to the tubercula quadrigemina and optic thalami. *p.* Anterior pyramids. *v.* Pons Varolii. *n*, *b.* Tubercula quadrigemina. *g.* Geniculate body of the optic thalamus. *t.* Processus cerebelli ad testes. *a.* Anterior lobe of the brain. *q.* Posterior lobe of the brain.

not observe convolutions in it. It appears rather to consist of laminæ in superposition, separated from each other by furrows. We shall see,

[1] Carpenter, Human Physiology, p. 215, Lond., 1842.

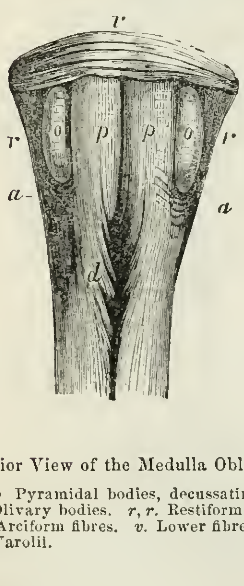
hereafter, that the number of cerebral convolutions has been esteemed, in some respects, to accord with the intellect of the individual; and Malacarne asserts, that he has observed a similar correspondence, as regards the number of laminæ composing the cerebellum; that he found only three hundred and twenty-four in the cerebellum of an insane individual; whilst in others he had counted upwards of eight hundred.

From the medullary part of the cerebellum, two large white cords pass to the pons Varolii, having the same disposition as the crura cerebri. They are the *crura cerebelli.*

Owing to the peculiar arrangement of the white and gray cerebral substances, when one of the hemispheres of the cerebellum is divided vertically, an arborescent appearance is presented,—the trunks of the arborization being white, the surrounding substance gray. This appearance is called *arbor vitæ.* The part where all these arborizations meet, near the centre of the cerebellum, is called *corpus denticulatum* seu *rhomboïdale.* Gall was of opinion, that this body has great agency in the production of the cerebellum. Lastly, the cerebellum covers the posterior part of the medulla oblongata, and forms with it a cavity, called *fourth ventricle.*

The *medulla oblongata* is so called, because it is the continuation of the medulla spinalis in the cavity of the cranium. It is likewise termed *mésocéphale*, from its being continuous with the spinal marrow in one direction, and sending towards the brain strong prolongations—crura

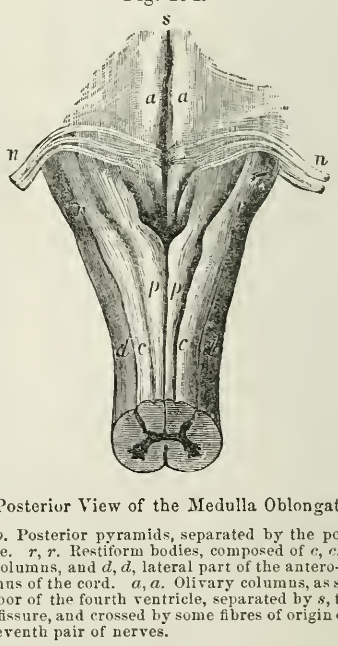
Fig. 193.



Anterior View of the Medulla Oblongata.

p, *p* Pyramidal bodies, decussating at *d*. *o*, *o*. Olivary bodies. *r*, *r*. Restiform bodies. *a*, *a*. Arciform fibres. *v*. Lower fibres of the pons Varolii.

Fig. 194.



Posterior View of the Medulla Oblongata.

p, *p*. Posterior pyramids, separated by the posterior fissure. *r*, *r*. Restiform bodies, composed of *c*, *c*, posterior columns, and *d*, *d*, lateral part of the antero-lateral columns of the cord. *a*, *a*. Olivary columns, as seen on the floor of the fourth ventricle, separated by *s*, the median fissure, and crossed by some fibres of origin of *n*, *n*, the seventh pair of nerves.

cerebri; and to the cerebellum similar prolongations—crura cerebelli; so that it appears to be the bond of union between these various parts. In its lower portion, it seems to be merely a continuation of the medulla spinalis, except that it is more expanded superiorly where it joins the pons Varolii. This portion of the medulla oblongata is called, by some, *tail of the medulla oblongata;* by others, the *rachidian bulb;* and, by others again it is regarded as the medulla oblongata. Its lower surface rests on the basilary gutter of the occipital bone, and exhibits a groove which divides the spinal cord into two portions. On each side of this furrow are two oblong eminences, the innermost of which is called *corpus pyramidale*, the outermost, *corpus olivare.* These oval bodies are surrounded by a superficial groove, which, in some instances, is partially interrupted by arciform fibres, which cross it at its lower part. At the lower third of the medulla oblongata, fibres of the anterior pyramids decussate, and form an anatomical demarcation between the medulla oblongata and the spinal cord. The decussation takes place by from three to five bundles of fibres from each pyramidal body. This decussation, as will be seen hereafter, is interesting in regard to the cross effect induced by certain diseases of the brain. On the posterior surface of the medulla oblongata, the posterior fasciculi separate to form the fourth ventricle: at the sides of this ventricle are the *corpora restiformia*, or *inferior peduncles of the cerebellum*,—so called because they seem to aid in the formation of that part of the encephalon; and on the inner side of each corpus restiforme is the small body —the *posterior pyramid.* Again, in addition to the corpora pyramidalia and olivaria—which derive their origin from, or are continuous with, the anterior and lateral fasciculi of the spinal cord, and are destined, according to some, to form the brain,—and the corpora restiformia, which are continuations of the posterior fasciculi, and are destined to form the cerebellum, there exist, according to some anatomists, other fasciculi in the rachidian bulb. All these are interesting points of anatomy, but are not of so much importance physiologically; notwithstanding even the views promulgated by Sir Charles Bell.[1] He considers that a column exists between the corpora olivaria and corpora restiformia, which extends below through the whole spine, but above does not proceed farther than the point where the rachidian bulb joins the tuber annulare; and that this column gives origin to a particular order of nerves—the respiratory. The corpora olivaria, and the posterior corpora pyramidalia, are regarded by Mr. Solly[2] as ganglia;—the former of the function of respiration, the latter of the sense of hearing.

The anterior and upper half of the medulla oblongata bears the names *pons Varolii*, *tuber annulare*, and *nodus cerebri;* and to this are attached, superiorly, the *corpora* or *tubercula quadrigemina.* In the very centre of the pons, the crura cerebri bury themselves; and by many they are considered to decussate; by others, to be prolongations of the anterior column of the spinal marrow. Sir C. Bell thinks, that the pons Varolii stands in the same relation to the lateral portions of the cerebellum, that the corpus callosum does to the cerebrum;—that it is the great commissure of the cerebellum, uniting its lateral parts, and associating the two organs.

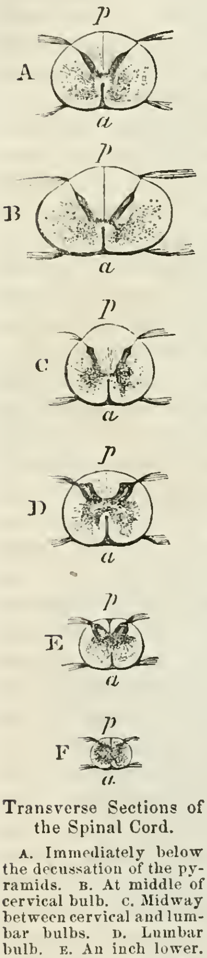
[1] The Nervous System of the Human Body, from Transactions of the Royal Society from 1821 to 1829, London, 1830; reprinted in this country, Washington, 1833.

[2] The Human Brain, its Configuration, Structure, Development, and Physiology, &c., p. 147, London, 1836. See, on this subject, Dr. John Reid, On the Anatomy of the Medulla Oblongata, in Edinb. Med. and Surg. Journ., Jan., 1841, p. 12.

The medulla oblongata consists chiefly of the centres of the nerves of respiration and deglutition, which, as elsewhere shown, are strictly reflex in their action.

2. The *spinal marrow* extends, in the vertebral canal, from the foramen magnum of the occipital bone above to the first or second lumbar vertebra, where it terminates in the *cauda equina.* It is chiefly composed of medullary matter, but not entirely so. Within, the cineritious substance is ranged irregularly, but has a crucial form when a section is made. The marginal illustrations exhibit sections of the spinal cord of man at different points; and the proportion of gray and white matter at each. From the calamus scriptorius in the fourth ventricle, and the rima formed by the corpora pyramidalia before, two fissures extend downwards, which divide the spinal marrow into lateral portions. The two lateral portions are divided by some into an anterior and a posterior, so that the cord is considered to have four distinct portions. It is generally, however, described as consisting of three columns—an *anterior*, a *posterior*, and a *middle* or *lateral.* The antero-lateral column, as seen in Fig. 192, is traceable through the medulla oblongata and pons Varolii to the corpora striata; and the postero-lateral to the thalami nervorum opticorum.

Fig. 195.



Transverse Sections of the Spinal Cord.

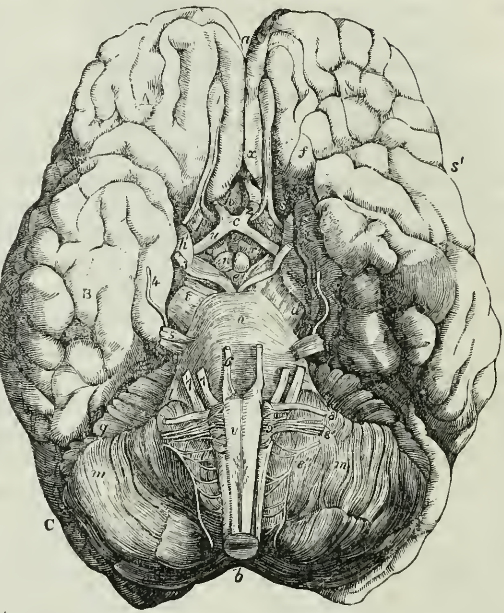
A. Immediately below the decussation of the pyramids. B. At middle of cervical bulb. C. Midway between cervical and lumbar bulbs. D. Lumbar bulb. E. An inch lower. F. Very near the lower end. *a.* Anterior surface. *p.* Posterior surface. The points of emergence of the anterior and posterior roots of the nerves are also seen.

The vertebral canal is lined by a strong ligamentous sheath, running down its whole length. The dura mater likewise envelopes the medulla at the occipital foramen, being firmly united to the ligaments; but farther down it constitutes a separate tube. The tunica arachnoidea from the brain adheres loosely to the cord, having the cephalo-spinal fluid within it; and the pia mater closely embraces it.

3. *Nerves.*—The nerves are cords of the same nervous substance as that which composes the encephalon and spinal marrow; extending from these parts, and distributed to the various organs of the body, many of them interlacing in their course, and forming *plexuses:* others having knots or *ganglions*, and almost all vanishing in the parts to which they are distributed. The generality of English anatomists reckon thirty-nine or forty pairs of nerves; the French, with more propriety, forty-two. Of these, nine, according to the English—twelve, according to the French—draw their origin from, or are connected with, the encephalon; and are hence called *encephalic* nerves; and thirty or thirty-one from the medulla spinalis; and hence termed *spinal.* The encephalic nerves emerge from the cranium by means of foramina at its base. They are—proceeding from before to behind—the *first pair* or *olfactory*, distributed to the organ of smell; the *second pair* or

optic, the expansion of which forms the retina; the *third pair*, *motores oculi* or *common oculo-muscular*, which send filaments to most of the muscles of the eye; the *fourth pair*, *trochleares*, *pathetici* or *internal oculo-muscular*, distributed to the greater oblique muscle of the eye; the *fifth pair*, *trifacial*, *trigemini* or *symmetrical nerve of the head*, (Bell,) which send their branches to the eye, nose, and tongue; the *sixth pair*, *abducentes* or *external oculo-muscular*, which are distributed to the abductor or rectus externus oculi; the *facial nerve*, *portio dura* of the seventh pair, *nervus communicans faciei* or *respiratory nerve of the face*, distributed to the muscles of the face; the *acoustic nerve*, *auditory nerve* or *portio mollis* of the seventh pair, which passes to the organ of hearing; the *eighth pair*, *pneumogastric*, *par vagum* or *middle sympathetic*, which is dispersed particularly on the larynx, lungs, heart, and stomach; the *glosso-pharyngeal*, often considered as part of the last, and whose name indicates its distribution to the tongue and pharynx; the great *hypoglossal*, *ninth pair* or *lingual nerve* distributed to the tongue; and the *spinal accessory* of Willis, which arises from the spinal cord in the cervical region; ascends into the cranium, and issues by one of the foramina to be distributed to the muscles of the neck. All these proceed, perhaps, from the medulla oblongata;—the brain and cerebellum not furnishing one.

Fig. 196.



Shows the under Surface or Base of the Encephalon freed from its Membranes.

A, anterior, B, middle, and C, posterior lobe of cerebrum.—*a*. The fore part of the great longitudinal fissure. *b*. Notch between hemispheres of the cerebellum. *c*. Optic commissure. *d*. Left peduncle of cerebrum. *e*. Posterior perforated space. *e* to *i*. Interpeduncular space. *f*, *f'*. Convolution of Sylvian fissure. *h*. Termination of gyrus fornicatus behind the Sylvian fissure. *i*. Infundibulum. *l*. Right middle crus or peduncle of cerebellum. *m*, *m*. Hemispheres of cerebellum. *n*. Corpora albicantia. *o*. Pons Varolii, continuous at each side with middle crura of cerebellum. *p*. Anterior perforated space. *q'*. Horizontal fissure of cerebellum. *r*. Tuber cinereum. *s*, *s'*. Sylvian fissure. *t*. Left peduncle or crus of cerebrum. *u*, *u*. Optic tracts. *v*. Medulla oblongata. *x*. Marginal convolution of the longitudinal fissure.—1 to 9 indicate the several pairs of cerebral nerves, numbered according to the usual notation, viz., 1. Olfactory nerve. 2. Optic. 3. Motor nerve of eye. 4. Pathetic. 5. Trifacial. 6. Abducent nerve of eye. 7. Auditory, and 7'. Facial. 8. Glosso-pharyngeal, 8'. Vagus, and 8''. Spinal accessory nerve.

The thirty or thirty-one spinal nerves on each side make their exit by the intervertebral foramina, and are divided into eight *cervical*, twelve *dorsal*, five *lumbar*, and five or six *sacral*.

The encephalic nerves are irregular in their formation, and, with the exception of the fifth pair, originate from one root. Each of the spinal nerves arises from two fasciculi, the one anterior, and the other posterior: these roots are separated from each other by the *ligamentum denticulare;* but they unite beyond this ligament, and near the intervertebral foramen present one of those knots, known under the name of *ganglions* or *ganglia*, in the formation of which the posterior root is alone concerned.

When the nerves have made their exit from the cranium and spine, they proceed to the organs to which they have to be distributed; ramifying more and more, until they are ultimately lost sight of, even when vision is aided by a powerful microscope. It is not positively decided, whether the nervous fibres have any distinct terminations either in the nervous centres, or in the organs to which they are distributed. In the gray matter of the brain of the vertebrata, they have been considered to form a kind of plexus of loops; and the ultimate fibres do not seem to anastomose. The following has been described as the mode in which the nervous fibres are generally distributed to the peripheral organs. The trunks subdivide into small fasciculi, each of which consists of from two to six fibres, and these form plexuses, whose arrangement bears a general resemblance to that of the elements of the tissue in which they are placed. The primitive fibres then separate; and each, after passing over several elementary parts of the containing tissue, or after forming a single narrow loop, as in the sensory papillæ, returns to the same or to an adjoining plexus, and pursues its way to the nervous centre from which it set out. According to this view, there is no more a termination of nerves, than there is of bloodvessels. Both form circles. More recent observations seem, however, to have demonstrated, that in different situations the loop-like appearance is fallacious; and that the ultimate fibres divide into fibrils, the terminations of which are lost in the tissues. It is probable, indeed, that this may be the general mode of termination.

Investigations by Henle and Kölliker[1] show, that some of the peripheral nervous fibrils terminate in small bodies, seated especially in the nerves of the fingers and toes, which have been called *Pacinian* or *Vaterian corpuscles;* but of whose uses little can be said. They have not been observed on any motor nerves, so that they would not seem to have anything to do with motion. They exist in many nerves of the sympathetic class, and are not present on many sensitive nerves; so that, it has been properly inferred, they are probably not connected with acuteness of sensation.

Another example of the termination of a nerve is in the so-called *tactile* or *touch corpuscles*, *axile bodies*, composed of a horizontally laminated mass of areolar tissue, which are found in the papillæ of parts endowed with great tactile sensibility, and into which the nerves of touch enter.

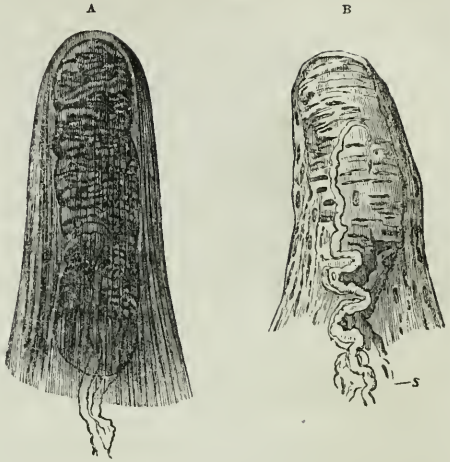
[1] Ueber die Pacinischen Körperchen an den Nerven des Menschen und der Saugethiere, Zürich, 1844; reviewed in Brit. and For. Med. Rev., January, 1845, p. 78; Todd and Bowman, Physiological Anat. and Physiology of Man, i. 395, London, 1845, or Amer. edit., Philad., 1850; and W. Bowman, Cyclopædia of Anat. and Physiol., by Dr. Todd, pt. xxvii. p. 876, Lond., Mar., 1846. See, on their discovery by Vater, Strahl, in Müller's Archiv. für Anatomie, u. s. w., Berlin, 1848; and the Author's Medical Dictionary, art. Corpuscles, Pacinian, 13th edit., Philad., 1856.

Fig. 197. Fig. 198.

Pacinian Corpuscles.

A. Nerve from the finger, natural size; showing the Pacinian corpuscles.
B. Unusual form, from the mesentery of the cat; showing two included in a common envelope:—*a*, *b* are the two nerve-tubes belonging to them.

Fig. 199.

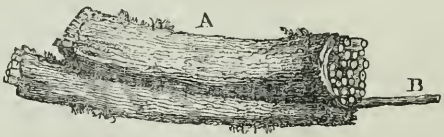


Tactile Corpuscles from the Skin of the Palmar Surface of the Forefinger.

A, in the natural state; B, treated with acetic acid.

Of the encephalic nerves, the olfactory, auditory, and acoustic—nerves of special sensibility—clearly pass on to their destination, without communicating with any other nerve. The spinal nerves, at their exit from the intervertebral foramina, divide into two branches, an anterior and a posterior, one being sent to each aspect of the body. The anterior branches of the four superior cervical pairs form the *cervical plexus*, from which all the nerves of the neck arise; the last four cervical pairs and the first dorsal form the *brachial plexus*, whence proceed the nerves of the upper extremities; whilst the branches of the five lumbar nerves, and the five sacral form the *lumbar* and *sciatic plexuses;* the former of which gives rise to the nerves distributed to the parts within the pelvis; the second to those of the lower limbs. The anterior branches, moreover, at a little distance from the exit of the nerve from the vertebral canal, communicate with an important and unique portion of the nervous system, the *great sympathetic.*

Fig. 200.



A Nerve consisting of many smaller Cords or Funiculi wrapped up in a common areolar Sheath.

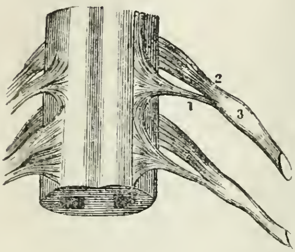
A. The nerve. B. A single funiculus drawn out from the rest.

Each nerve consists of numerous fasciculi surrounded by areolar membrane; and, according to Reil,[1] of an external envelope, called *neurilemma*, which, in the opinion of most anatomists, is nothing more than a fibro-areolar envelope, similar to that which surrounds the vessels and muscular fibres.

[1] De Structurâ Nervorum, Hal., 1796.

Until of late years, the nerves were universally divided, according to their origin, into *encephalic* and *spinal;* but, more recently, anatomical divisions have been proposed, based upon the uses they appear to fulfil in the economy. For one of the most beautiful of this kind we are mainly indebted to Sir Charles Bell. It has been already seen, that the encephalic nerves are connected with the encephalon by one root, whilst the spinal nerves arise from two; the one connected with the anterior tract of the spinal marrow; the other with the posterior. If these different roots be experimented on, we meet with results varying considerably. If we divide the anterior root, the part to which the nerve is distributed is deprived of motion; if the posterior root be cut, the part is deprived of sensibility. We conclude, therefore, that each of the spinal nerves consists of filaments destined for both motion and sensation; that the encephalic nerves, which have but one root, are destined for one of these exclusively, and that they are either nerves of motion, or of sensation, according as their roots arise from the anterior or the posterior tract of the medulla.

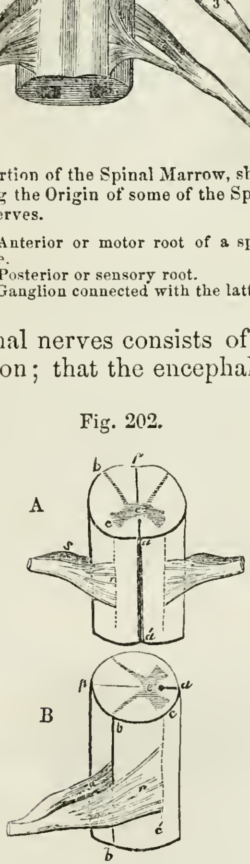
Fig. 201.



A portion of the Spinal Marrow, showing the Origin of some of the Spinal Nerves.

1. Anterior or motor root of a spinal nerve.
2. Posterior or sensory root.
3. Ganglion connected with the latter.

Fig. 202.



Plans in outline, showing the Front A, and the Side B, of the Spinal Cord, with the Fissures upon it; also sections of the Gray and White Matter, and the Roots of the Spinal Nerves.

a, a. Anterior. *p, p.* Posterior fissure. *b.* Posterior, and *c.* Anterior horn of gray matter. *e.* Gray commissure. *a, e, c.* Anterior white column. *c, e, b.* Lateral columns. *a, e, b.* Antero-lateral column. *b, e, p.* Posterior columns. *r.* Anterior, and *s.* Posterior roots of a spinal nerve.

It has already been remarked, that the medulla oblongata, according to some anatomists, is composed of three fasciculi or columns on each side;—an *anterior*, a *middle*, and a *posterior;* and it has been affirmed by Sir Charles Bell, that whilst the anterior column gives origin to nerves of motion; and the posterior to nerves of sensation; the middle gives rise to a third order, having the function of presiding over the respiratory movements; and which Sir Charles, accordingly, calls *respiratory nerves.* To this third order belong,—the *accessory nerve* of Willis or *superior respiratory;* the *vagus;* the *glosso-pharyngeal;* the *facial*, called by him the *respiratory nerve of the face;* the *phrenic;* and another having the same origin—the *external respiratory.* Sir Charles's views, if admitted, lead, consequently, to the belief, that there are at least three sets of nerves,—one destined for sensation; another for motion; and a third for a particular kind of motion—the respiratory; and that every nerve of motion communicates to the muscles, to which it is distributed, the power of aiding, or taking part in, motions of one kind or another; so that a muscle may be paralyzed, as regards certain movements, by the section of one nerve, and yet be capable of others of a different kind, by means of the nerves that are uninjured.

Yet this division is now by no means generally admitted; and even by some who are of opinion, that the sensory and motor filaments arise from distinct tracts of the spinal cord, it is denied that this is the case with those that originate from the upper part of the cord; there being in the medulla oblongata a blending of the sensory and motor tracts which cannot easily be explained. Pathological cases, too, occasionally occur, which throw great difficulty on this matter. Two of the kind have been related by Mr. Stanley and Dr. Budd,[1] in which there was disease confined to the posterior column; yet sensation remained unimpaired, whilst the power of motion in the lower extremities was lost.

Much evidently remains to be accomplished, before the precise arrangement of the columns of the spinal cord, and of the relations of the nerves connected with them, can be esteemed established. Sir Charles Bell,[2] indeed, subsequently renounced his first opinion, that the posterior roots of the spinal nerves proceed from the posterior column, and described them as arising from the middle or lateral column; affirming, at the same time, that it is not impossible that the posterior column may be connected with the sensory roots of the spinal nerves, although he has not hitherto succeeded in tracing it. Messrs. Grainger and Swan maintain, that both sets are connected with the lateral columns only; the anterior and posterior lateral fissures definitely limiting the two roots. Perhaps, as has been suggested,[3] both these statements may be too exclusive. The anterior roots would seem to have a connexion with both the anterior and lateral columns; and the posterior cannot be said to be restricted to the lateral column, some of their fibres entering the posterior division of the cord.

Most physiologists are now of opinion, both from experiment and reflection, that there is no special column destined for respiration, and that there appears to be nothing so peculiar in the action of the respiratory muscles, that they should require a distinct set of nerves.[4]

Sir C. Bell proposed a further arrangement of the nerves, more natural and philosophical than the unmeaning numeration according to the system of Willis, and better adapted to facilitate the comprehension of this intricate portion of anatomy. According to this, all the nerves of the body may be referred to two great classes—the *original*, *primitive* or *symmetrical*,—and the *irregular* or *superadded*. It has been already remarked, that a division of the spinal cord has been presumed to correspond to the cerebrum; and another to the cerebellum. Now, every *regular nerve* has two roots, one from the anterior of these columns, and another from the posterior. Such are the fifth pair; the sub-occipital; the seven cervical; the twelve dorsal; the five

[1] Medico-Chirurgical Transactions, vol. xxiii., Lond., 1840.
[2] Nervous System, &c., 3d edit., p. 234, London, 1836.
[3] Carpenter, Principles of Human Physiology, 2d Amer. edit., p. 125, Philad., 1845.
[4] Dr. Reid, op. cit., Jan., 1838, p. 175.

lumbar; and the five or six sacral,—that is, thirty-one or thirty-two perfect, regular, or double nerves,—including, to state more briefly, all the spinal nerves, and one encephalic—the fifth pair. The fifth pair is found to arise from the encephalon by two roots, and to have a ganglion upon the posterior root. It is, accordingly, classed with the spinal nerves; and, like them, according to Sir Charles Bell, conveys both motion and sensibility to the parts to which it is distributed. These regular nerves are common to all animals, from the zoophyte to man. They run out laterally; or in a direction perpendicular to the longitudinal division of the body; and never take a course parallel to it. The other class is called *irregular* or *superadded.* The different nervous cords, proceeding from it, are distinguished by a simple fasciculus or single root. All these are simple in their origins; irregular in their distribution; and deficient in that symmetry which characterizes those of the first class. They are superadded to the original class; and correspond to the number and complication of the superadded organs. Of these, there are the *third*, *fourth*, and *sixth*, distributed to the eye; the *seventh*, to the face; the *ninth*, to the tongue; the *glosso-pharyngeal*, to the pharynx; the *vagus*, to the larynx, heart, lungs, and stomach; the *phrenic*, to the diaphragm; the *spinal accessory*, to the muscles of the shoulders; and the *external respiratory*, to the outside of the chest. The reason of the seeming confusion in this latter class is to be looked for in the complication of the superadded apparatus of respiration, and in the variety of offices it has to perform in the higher classes of animals.

Fig. 203.

Roots of a Dorsal Spinal Nerve, and its union with the Sympathetic.

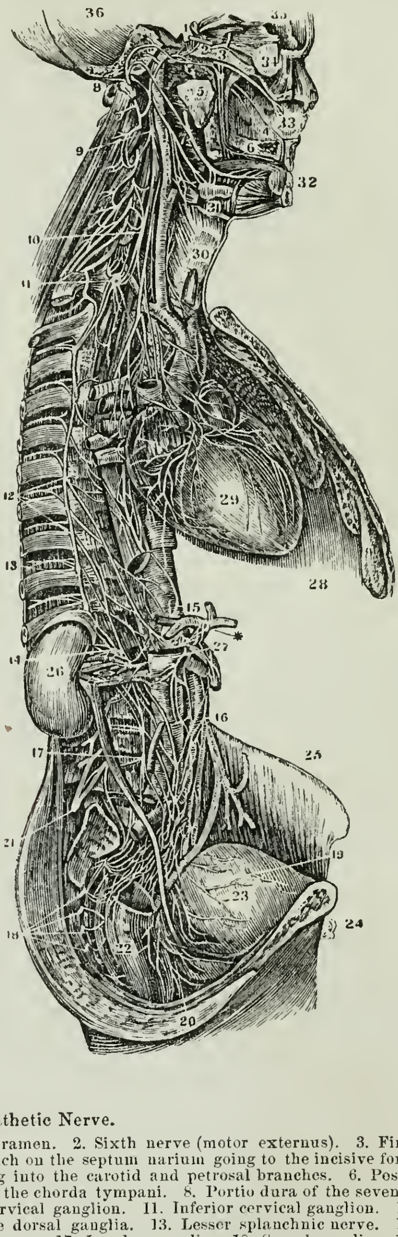
c, c. Anterior fissure of the spinal cord. *a.* Anterior root. *p.* Posterior root, with its ganglion. *a'.* Anterior branch. *p'.* Posterior branch. *s.* Sympathetic. *e.* Its double junction with the anterior branch of the spinal nerve by a white and a gray filament.

4. *Great Sympathetic.* — This nerve, called also *trisplanchnic*, *splanchnic*, *ganglionic*, *great intercostal*, *vegetative*, and *organic* is constituted of a series of ganglions, joined to each other by a nervous trunk, and extending down the side of the spine, from the base of the cranium to the os coccygis or lowest bone. It communicates with each of the spinal nerves, and with several of the encephalic; and from the ganglions, formed by such communication, sends off nerves, which accompany the arteries, and are distributed particularly to the organs of involuntary functions. At its upper part, it is situate in the carotid canal, where it appears under the form of a ganglionic plexus; two fila-

ments of which proceed to join the sixth pair of encephalic nerves, and another to meet the Vidian twig of the fifth pair. By means of the fifth pair, it communicates also with the ophthalmic ganglion, which Bichat considered to belong to it. On issuing from the carotid canal, the nerve passes downwards, along the side of the spine, to the sacrum; presenting a series of ganglions;—three in the neck, —the *superior*, *middle*, and *inferior cervical;* twelve in the back,—the *thoracic;* five in the loins,—the *lumbar;* and three or four in the sacrum,—the *sacral*. When it reaches the coccyx, it terminates by a small ganglion, called *coccygeal;* or by uniting with the great sympathetic of the opposite side.

The ganglions are of an irregular, but generally roundish, shape. They consist of nervous filaments, surrounded by a reddish-gray, pulpy, albuminous, or gelatinous substance, which differs from the gray matter of the brain. Sir E. Home[1] considers their structure to be intermediate between that of brain and nerves; the brain being composed of small globules suspended in a transparent elastic jelly; the nerves made up of single rows of globules, and the ganglions consisting of a congeries of nervous fibres compacted together.[2] Volk-

Fig. 204.



Great Sympathetic Nerve.

1. Plexus on the carotid artery in the carotid foramen. 2. Sixth nerve (motor externus). 3. First branch of the fifth, or ophthalmic nerve. 4. A branch on the septum narium going to the incisive foramen. 5. Recurrent branch or Vidian nerve dividing into the carotid and petrosal branches. 6. Posterior palatine branches. 7. Lingual nerve joined by the chorda tympani. 8. Portio dura of the seventh pair. 9. Superior cervical ganglion. 10 Middle cervical ganglion. 11. Inferior cervical ganglion. 12. Roots of the great splanchnic nerve arising from the dorsal ganglia. 13. Lesser splanchnic nerve. 14. Renal plexus. 15. Solar plexus. 16. Mesenteric plexus. 17. Lumbar ganglia. 18. Sacral ganglia. 19. Vesical plexus. 20. Rectal plexus. 21. Lumbar plexus (cerebro-spinal). 22. Rectum. 23. Bladder. 24. Pubis. 25. Crest of the ilium. 26. Kidney. 27. Aorta. 28. Diaphragm. 29. Heart. 30. Larynx. 31. Submaxillary gland. 32. Incisor teeth. 33. Nasal septum. 34. Globe of the eye. 35, 36. Cavity of the cranium.

[1] Lect. on Comp. Anat., v. 194, Lond., 1828.

[2] See, on the Histology of the Organic or Sympathetic Nervous Fibres, Mr. Paget, Brit. and For. Med. Rev., July, 1842, p. 279.

man and Bidder, and Reichert,[1] consider the sympathetic nerve-fibres to be distinct in size and structure from the cerebro-spinal; but Valentin and others maintain there is no difference.

Authors are by no means agreed with regard to the uses of these ganglions. Willis,[2] Haller,[3] and others, considered them to be small brains for the secretion of the nervous fluid or animal spirits; an opinion, which was embraced by Richerand,[4] and Cuvier;[5] the latter of whom remarks, that the ganglia are larger and more numerous when the brain is deficient in size. Lancisi,[6] and Vicq d'Azyr, regarded them as a kind of heart for the propulsion of these spirits, or as reservoirs for keeping them in deposit. Scarpa[7] treats them as synonymous with plexuses; but plexuses with the filaments in close approximation; and plexuses he regards as ganglions, the filaments of which are more separated. He consequently believes, with many physiologists, that their office is to commingle and unite various nervous filaments with each other. Dr. Wilson Philip[8] thinks, that they are secondary sources of nervous influence; that they receive supplies of it from all parts of the brain and spinal marrow, and transmit the united influence to the organs to which the nerves are distributed; whilst some conceive, that at least one office is to communicate irritability to the tissues.[9] Johnstone,[10] Reil,[11] Bichat,[12] and others, are of opinion that their use is to render the organs, which derive their nerves from them, independent of the will.

These views are sufficiently discordant; and well indicate the intrinsic obscurity of the subject. That of Dr. Philip is the most probable. Containing the vesicular or gray matter, which seems to be everywhere, perhaps, concerned in the production of nerve-power, the ganglia may be regarded as agents of nervous reinforcement; although we may remain uncertain as to the mode in which their office is executed.[13] It is affirmed by M. Robin, in a communication made by him to the *Académie des Sciences*, of Paris, in June, 1847, that the ganglia of the great sympathetic and of the cerebro-spinal nerves enclose the same

[1] Müller's Archiv., 1844, cited by Mr. Paget, in Brit. and For. Med. Rev., April, 1845, p. 572.

[2] Cerebri Anatome cui accessit Nervorum Descriptio, &c., cap. xxvi., Lond., 1664.

[3] De Verâ Nervi Intercostalis Origine, Gotting., 1793; Collect. Dissert. Anat., ii. 939; and Oper. Minor, i. 503.

[4] See Appendix to Eng. edit., by Dr. Copland.

[5] Leçons d'Anatomie Compar. Introd., p. 26.

[6] Dissert. de Structurâ Usuque Gangliorum ad J. B. Morgagnium, in Morgagni Adver. Anat., v. 101, Lugd. Bat., 1741.

[7] De Nervis Comment., cap. ii. 320.

[8] Philosoph. Transact. for 1829; and Inquiry into the Nature of Sleep and Death, Lond., 1834, p. 14.

[9] Fletcher, Rudiments of Physiology, P. ii. *a*. p. 68, Edinb., 1836.

[10] Philosophical Transactions, vols. 54, 57, and 60; Essays on the Use of the Ganglions of the Nerves, Shrewsbury, 1771; and Medical Essays and Observations relating to the Nervous System, Evesham, 1795.

[11] Archiv. für die Physiol., S. 226, vii., Halle, 1807.

[12] Anatomie Générale, tom. i. 200, and ii. 405.

[13] See the excellent article by Wagner, entitled Sympathischer Nerv, Ganglienstructur und Nervenendigungen, in his Handwörterbuch der Physiologie, 17te Lieferung. S. 360, Braunschweig, 1847; another by Budge, on the Sympathetic, with special relation to the Heart's action, Ibid., S. 406; and on the Sympathetic Ganglia of the Heart by Wagner, Ibid., S. 450.

kind of ganglionary globules, and of elementary tubes, but in different proportions; and hence he does not regard them as separate nervous systems.

Although connected with the brain by the branches of the fifth and sixth pairs of encephalic nerves, and with the spinal cord by the spinal nerves, the sympathetic does not appear to be directly influenced by either; as the functions of the parts to which its ramifications are distributed continue for some time after both brain and spinal marrow have been separated; nay, as in the case of the heart and intestines, after they have been removed from the body. Yet many discussions have been indulged regarding the origin of this important part of the nervous system; some assigning it to the brain, others to the spinal marrow; whilst others again esteem it a distinct nerve, communicating with the brain and spinal cord, but not originating from either; receiving, according to M. Broussais,[1] by the cerebral nerves, the excitant influence, and applying it to movements that are independent of the centre of perception. In like manner, he affirms, when irritation predominates in the viscera, it is conveyed by the ganglionic to the cerebral nerves, which transmit it to the brain. Reil and Bichat, esteeming the sympathetic to be the great nervous centre of involuntary functions, have termed it the *organic nervous system*, in contradistinction to the *animal nervous system*, which presides over the animal functions; whilst Lobstein,[2] who has published an *ex professo* work on the subject, assigns three functions to it. 1. To preside over nutrition, secretion, the action of the heart, and the circulation of the blood; 2. To maintain a communication between different organs of the body; and 3. To be the connecting medium between the brain and abdominal viscera. Remak,[3] who believes that the animal economy possesses two sensoriums,—the one in the cerebro-spinal axis, the other in the ganglionic system,—considers, that as in the cerebro-spinal system of nerves two orders of phenomena occur,—the perception of sensation, and the reaction or reflection of volition; so, in the organic nervous system, two analogous actions take place,—organic perception, or, as it has been called, Hallerian irritability, and reaction or organic reflection, as shown by J. Müller.[4]

From the result of his own researches, Dr. Carpenter[5] inferred, that the sympathetic system does not exist in the lowest classes of animals in a distinct form;—that the nervous system of the invertebrata, taken as a whole, bears no analogy to it, and that as the divisions of this become more specialized, some appearance of a separate sympathetic presents itself, but it is never so distinct as in the vertebrata; hence he deduces, and with probability, that as the sympathetic system is

[1] A Treatise on Physiology applied to Pathology, translated by Drs. John Bell, and R. La Roche, p. 257, Philad., 1832.

[2] De Nervi Sympath. Human., &c., translated by Dr. Pancoast, Philad., 1831.

[3] Ammon's Monatschrift, June, 1840; and Edinb. Med. and Surg. Journal, Jan., 1841, p. 249.

[4] Elements of Physiology, by Baly, i. 736, Lond., 1838.

[5] Dissertation on the Physiological Inferences to be deduced from the Structure of the Nervous System in the Invertebrated Classes of Animals, Edinb., 1839; reprinted in Dunglison's Med. Library, Philad., 1839; also, his Principles of Human Physiology, p. 111, London, 1842.

not developed in proportion to the predominant activity of the functions of organic life, but in proportion to the developement of the higher division of the nervous system, its office is not to preside over the former, but to bring them in relation with the latter; so that the actions of the organs of vegetative life are not dependent upon it, but influenced by it in accordance with the operations of the system of animal life.

Again, the great sympathetic has been esteemed to be the visceral nerve *par excellence*, or the one that supplies the different viscera with their nervous influence,—a part of its office as the presumed nervous system of organic functions. On examining its course, we find many filaments proceeding from the cervical and thoracic ganglions, interlacing and forming the cardiac plexus, from which the nerves of the heart and great vessels arise. The same thoracic ganglions furnish a branch to each intercostal artery. A nerve of the great sympathetic—called the *great splanchnic* or *visceral*—proceeding from some of the thoracic ganglions, passes through the pillars of the diaphragm into the abdomen, and terminates in the large plexus or ganglion, called the *semilunar;* and this by uniting with its fellow of the opposite side, constitutes the still more extensive interlacing,—the *solar plexus*. From this, numerous filaments proceed, which—by accompanying the coronaria ventriculi, hepatic, splenic, spermatic, renal, superior and inferior mesenteric, and hypogastric arteries—are distributed to the parts supplied with blood by these arteries,—the stomach, liver, spleen, testes, kidneys, intestines, &c. Weber,[1] however, who examined the great sympathetic in different animals, affirms, that the splanchnic may not be the sole *visceral* nerve, but that the eighth pair may share in the function. He states, that the great sympathetic is less developed, the lower the animal is in the scale; whilst the eighth pair is more and more developed as we descend, and at length is the only visceral nerve in some of the mollusca. Sir A. Cooper's[2] experiments satisfied him, that this nerve is essential to the digestive process; but of this we shall have to speak hereafter. In the prosecution of those experiments he found, that when the great sympathetic was tied on a dog, but little effect was produced; the animal's heart appeared to beat more quickly and feebly than usual; but of this circumstance he could not be positive, on account of the natural quickness of its action. The animal was kept seven days, at which time one nerve was ulcerated through, and the other nearly so, at the situation of the ligatures. Another animal on which the sympathetic had been tied nearly a month before, was still living when he wrote. When the pneumogastric or eighth pair, the phrenic, and the great sympathetic were all tied on each side, "the animal lived little more than a quarter of an hour, and died of dyspnœa."[3]

These experiments would appear to show, either that the great sympathetic is not so indispensable to the economy as has been imagined; or that it is, in every part, a generator of nervous influence, so that if its connexion with the brain or any other viscus be destroyed, the divided portions may still possess the power of generating nervous

[1] Anatom. Comparat. Nerv. Sympath., Lips., 1817.

[2] Guy's Hospital Reports, vol. i. p. 457, London, 1836.

[3] Ibid., p. 471.

agency. But if we admit this as regards the system of the great sympathetic, we shall find, that it is difficult to extend it to detached portions of the nervous system of animal life.

It must be confessed, that our knowledge of the uses of this great division of the nervous system is far from being precise; for whilst some physiologists believe it to be concerned in every involuntary and organic action; Dr. Proctor[1] thinks, that the nearest approach to a positive determination of its use that we can arrive at with our present limited knowledge is, that "it is for the purpose of regulating the tonic contraction of the arterial system, and for nothing else." One distinguished observer, M. Magendie,[2] inquires whether we have sufficient reason for the belief, that it is a nerve at all! and a writer of distinction, Dr. J. C. B. Williams,[3] admits, that nothing is definitely known as to the properties communicated by ganglionic nerves; and he adds: "Before the influence of the ganglionic system can be employed as an element in pathology, its existence must be proved, and its properties defined in physiology; this has not been done."

The experiments of M. Flourens,[4] exhibited that the semilunar is the only ganglion that shows any great sensibility; and hence it has been considered as a sort of intervention to connect the viscera with the encephalon.

5. *True Spinal, Excito-Motory* or *Reflex Nervous System.*—Until of late years, the nervous system was commonly divided into the cerebro-spinal and the sympathetic; although there were numerous functions of a reflex character, which could not be well explained by them; and which had attracted the attention of investigators into the actions of the nervous system.[5] We are indebted to Dr. Marshall Hall[6] for an additional division, which throws light on many of the obscure phenomena that had not previously received elucidation. He has proposed to divide all the nerves into 1. The cerebral or sentient and voluntary. 2. The true spinal or excito-motory. 3. The ganglionic or nutrient and secretory.

If the sentient and voluntary functions be destroyed by a blow on the head, the sphincter muscles still contract when irritated, because the irritation is conveyed to the spine, and the reflex action takes place to the muscle so as to throw it into contraction. But if the spinal marrow be now destroyed, the sphincters remain entirely motionless; because the centre of the system is destroyed. Dr. Hall thinks, that a peculiar set of nerves constitute, with the true spinal marrow as their axis, the second subdivision of the nervous system; and as those of the first subdivision are distinguished into sentient

[1] Medico-Chirurg. Rev., Jan., 1845, p. 182.

[2] Précis de Physiologie, 2de édit., i. 171, Paris, 1825.

[3] Principles of Medicine, 3d Amer. edit., by Dr. Clymer, p. 200, note, Philad., 1848.

[4] Recherches Expérimentales sur les Propriétés et les Fonctions du Système Nerveux, &c., 2de édit., p. 229, Paris, 1842.

[5] Whytt, An Essay on the Vital and other Involuntary Functions of Animals, Edinb., 1751; The Principles of Physiology, by John Augustus Unzer; and A Dissertation on the Functions of the Nervous System, by George Prochaska; translated and edited by Thomas Laycock, M. D., Sydenham Society's edit., London, 1851.

[6] Lectures on the Nervous System, Lond., 1836, or Amer. edit., Philad., 1836; also, his Lectures on the Theory and Practice of Medicine, in London Lancet, Feb. 3 and Feb. 7, 1838.

and voluntary, these may be distinguished into *excitor* and *motory*. The *first*, or excitor nerves, pursue their course principally from internal surfaces, characterized by peculiar excitabilities, to the vesicular centre of the medulla oblongata and medulla spinalis; the *second* or motor nerves pursue a reflex course from the medulla to the muscles, having peculiar actions concerned principally in ingestion and egestion. The motions connected with the first or cerebral subdivision are sometimes—indeed frequently—*spontaneous;* those connected with the true spinal are, he believes, always excited. Dr. Hall thinks that there is good reason for viewing the fifth, and posterior spinal nerves as constituting an external ganglionic system for the nutrition of the external organs; and he proposes to divide the *ganglionic* subdivision of the nervous system into 1, the *internal* ganglionic, which includes that usually denominated the sympathetic, and probably filaments of the pneumogastric; and 2, the *external* ganglionic, embracing the fifth and posterior spinal nerves. To the *cerebral* system he assigns all diseases of sensation, perception, judgment, and volition,—therefore all painful, mental, and comatose, and some paralytic diseases. To the true *spinal* or *excito-motory* or *reflex* system belong all spasmodic and certain paralytic diseases. He adds, that these two parts of the nervous system influence each other both in health and disease, as they both influence the ganglionic system.[1] This reflex faculty is regarded by Dr. Brown-Séquard[2] as a vital property belonging to the spinal cord; and its source he refers to the nutrition, which maintains the organization of that nervous centre.

The views of Dr. Hall on the excito-motory function have been embraced by Müller,[3] Grainger,[4] Carpenter,[5] and indeed, with more or less modification, by almost all physiologists.[6] The last named gentleman inferred from his inquiries, that the actions most universally performed by a nervous system are those connected with the introduction of food into the digestive cavity, and that we have reason to regard this class of actions as every where independent of volition, and perhaps also of sensation,—the propulsion of food along the œsophagus, in man, being of this character;—that for the performance of any action of this nature, a nervous circle is requisite, consisting of an *afferent* nerve, on the peripheral extremities of which an impression is made,—a ganglionic centre, where the white fibres of which that nerve consists terminate in gray matter, and those of the efferent nerve originate in like manner; and an *efferent* trunk conducting to the contractile structure the motor impulse, which originates in some change between the gray and white matter;—that in the lowest animals such actions constitute nearly the entire function of the nervous system,—the amount of those involving sensation and volition being very small;

[1] Principles of the Theory and Practice of Medicine, by Marshall Hall, M. D., F. R. S., p. 243, London, 1837, and American edit. by Drs. Bigelow and Holmes, Bost., 1839.
[2] Medical Examiner, August, 1852, p. 483.
[3] Handbuch der Physiologie, S. 333, and S. 688, Coblenz, 1835, 1837, or the English translation by Dr. Baly, i. 707, London, 1838.
[4] On the Structure and Functions of the Spinal Cord, London, 1837.
[5] Op. cit.
[6] Todd and Bowman, the Physiological Anatomy and Physiology of Man, p. 312, London, 1845.

but as we ascend the scale, the evidence of the participation of true sensation in the actions necessary for acquiring food, as shown by the developement of special sensory organs, is much greater; but that the movements immediately concerned with the introduction of food into the stomach remain under the control of a separate system of nerves and ganglia, to the action of which the influence of the cephalic ganglia—the special if not the only seat of sensibility and volition—is not essential; that, in like manner, the active movements of respiration are controlled by a separate system of nerves and ganglia, and are not dependent upon that of sensation and volition, although capable of being influenced by it;—that whilst the actions of these systems are, in the lower tribes, almost entirely of a simply reflex character, we find them, as we ascend, gradually becoming subordinate to the will; and that this is effected by the mixture of fibres proceeding directly from the cephalic ganglia with those arising from their own centres;—that the locomotive organs, in like manner, have their own centres of reflex action, which are independent of the influence of volition, perhaps also of sensation:—that the influence of the will is conveyed to them by separate nervous fibres, proceeding from the cephalic ganglia, and that similar fibres probably convey to the cephalic ganglia the impressions destined to produce sensations;—that the stomato-gastric, respiratory, and locomotive centres are all united in the spinal cord of the vertebrata, where they form one continuous ganglionic mass, and that the nerves connected with all these likewise receive fibres derived immediately from the cephalic ganglia;—and lastly, that whenever peculiar consentaneousness of action is required between different organs, their ganglionic centres are united more or less closely; and that the trunks themselves are generally connected by bands of communication.

On the whole, in the present state of our knowledge, we are justified, perhaps, in adopting the systematic summary of the functions of the nervous system, and the general purposes to which it is inservient, as originally given by the writer last cited.[1] 1. The nervous system receives impressions, which, being conveyed by its *afferent* fibres to the sensorium, are there communicated to the conscious mind; and are inservient, in some manner, to the acts of that mind. As the result of these acts, a motor impulse is transmitted along *efferent* nerves to particular muscles, which excites them to contraction. Of these acts the encephalon, and nerves communicating with it, are the organs. 2. Certain parts of the nervous system receive impressions, which are propagated along *afferent* fibres that terminate in ganglionic centres distinct from the sensorium. In these, a reflex motor impulse is thus excited, which is transmitted along *efferent* trunks proceeding from those centres, and excites muscular contraction without any necessary intervention of sensation or volition. The organs of this function are the gray matter of the spinal cord, which is not continuous with the fibrous structure of the brain, and the trunks connected with it. It is the true *spinal* or *excito-motory* system of Dr. Hall. 3. There is yet a division of the nervous system, which appears to have for its object to

[1] Human Physiology, p. 79, London, 1842; see also Amer. edit., Philad., 1854.

combine and harmonize the muscular movements immediately connected with the maintenance of organic life. It may likewise influence, and connect with each other the functions of nutrition, secretion, &c.; although these—like the muscular movements immediately connected with the maintenance of organic life—are doubtless essentially independent of it; and—as has been shown—can be carried on where it does not exist. The organ of these acts is the great sympathetic. Of late—as will be seen hereafter—Dr. Carpenter[1] has contended with much force for the existence of a series of sensory ganglia, separate and distinct from those that compose the cerebrum and cerebellum—"ganglia of the nerves of sensation, common and special, which are superposed, as it were, on the medulla oblongata," and which, together, constitute the real sensorium.

It has been urged by Dr. Laycock,[2] in a paper read before the British Association at York, in accordance with views published by him four years previously, that the brain, although the organ of consciousness, is subject also to the laws of reflex action; and that in this respect it does not differ from other ganglia of the nervous system. He regards the cerebral nerves, and especially the optic, auditory, and olfactory, as afferent excitor nerves, along which impressions pass to the central axis; thence to be communicated to the motor nerves, and thus give rise to combined muscular acts, or to irregular spasmodic movements. Hydrophobia is adduced by him as a good illustration of these cerebral reflex movements. The acknowledged excito-motory phenomena in that disease may be induced.—*First.* Through the nerves of touch, as by the contact of water with the surface of the head, hands, chest, lips, and pharynx. *Secondly.* By a current of air impinging on the face or chest. *Thirdly.* By a bright surface, as a mirror. *Fourthly.* By the sight of water; and *Fifthly.* By the idea of water, as when it is suggested to the patient to drink. The author has been in the habit of offering as an example of the same kind, vomiting induced by the sight of a disgusting object. Here the impression is first made upon the brain through an organ of sense, and the reflex motor phenomena concerned in vomiting are instantaneously excited;—facts, which at least prove, that although the gray matter of the spinal marrow may continue to execute its functions, when those of the cerebro-spinal nervous system are suspended,—as during sleep or an attack of epilepsy,—it is capable of being excited to action by impressions made through the latter, in the same manner as by impressions made on the afferent spinal nerves themselves.

From all that has been said, it will be understood, that each nerve as it issues from the spinal canal must be composed of various fasciculi:—one, *sensory* or of sensation, connected with the posterior medullary tract, and continuous with the medullary matter of the brain; another, connected with the anterior medullary tract, and conveying the influence of volition from the brain along the spinal cord and nerves to the muscles; a third, consisting of *excitor* fibres, terminating

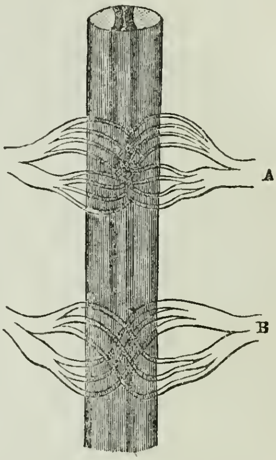
[1] Human Physiology, 4th Amer. edit., p. 320, Philad., 1850, and new edit., p. 488, Philad., 1855.

[2] British and Foreign Medical Review, Jan., 1845, p. 298; see also an interesting essay by him on the Functions of the Brain, in Brit. and For. Med.-Chir. Rev., July, 1855, p. 155.

in the gray or ganglionic matter of the cord, and conveying impressions to it; and a fourth, consisting of *motor* fibres, arising from the gray matter of the cord, and conveying the nervous influence reflected to the muscles.

It would appear that a part of each root enters the gray matter of the cord; whilst a part is continuous with the white or medullary matter; and Dr. Stilling[1] affirms—as the result of his researches—that of the fibres of the posterior roots some form loops in the gray matter, and become continuous with those of the anterior roots of the same side; whilst others cross the gray matter, and become continuous with those of the anterior roots of the opposite side. It has been shown, too, by Mr. Newport,[2] that there are other fibres, which pass from the posterior into the anterior roots of other nerves, above and below, both on the same and the opposite side.

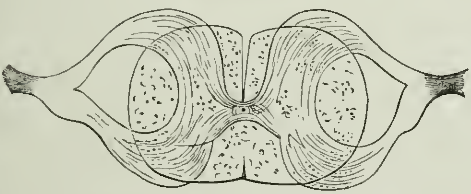
Fig. 205.



Structure of the Spinal Cord, according to Stilling.

A. Posterior fibres continuous with the anterior of the same side, through the nucleus of the cord. B. Posterior fibres continuous with the anterior of the opposite side.

Fig. 206.



Transverse Section of the Medulla.

The transverse gray fibres are the continuation of the roots of the nerves; the longitudinal white and gray fibres are indicated by points.

It has been a matter of daily observation, that hemorrhage into one hemisphere of the brain produces loss of sensation in the opposite side of the body; and the decussation of the sensory fibres has generally, perhaps, been considered to take place in the medulla oblongata; whilst some physiologists have referred it to the pons varolii, tubercula quadrigemina, and crura cerebri. Dr. Brown-Séquard,[3] however, found, from experiments on guinea-pigs, dogs, cats, sheep and rabbits, that in the case of a lesion of one side of the spinal cord, a diminution or loss of sensibility is produced on the opposite side of the body, whence he infers, that most of the impressions made on one side of the body are transmitted to the sensorium by the opposite side of the spinal cord. This is the reverse of what occurs in regard to motion;. for a lesion of the right side of the spinal cord causes a loss or diminution of voluntary movements in the same side of the body; and this is explained by the

[1] Untersuchungen über die Textur des Rückenmarks, von Dr. B. Stilling und Dr. J. Wallach, S. 51, Leipz., 1842.

[2] Philosophical Transactions, 1843, and Dr. Carpenter, 2d Amer. edit., p. 125, Philad., 1845.

[3] Medical Examiner, Nov. 1852, p. 708, and his Experimental and Clinical Researches on the Physiology and Pathology of the Spinal Cord and some other parts of the nervous centres, Richmond, 1855.

motor fibres decussating in the medulla oblongata only; whilst the decussation of the sensory occurs in every part of the spinal cord.

Much, doubtless, still remains to be accomplished, before we can consider views in regard to the nervous system established. Like many important questions of physiology, they may be regarded as in a transition state; but the zeal and activity of physiological inquirers are daily throwing light upon many points; and of these there are none surrounded with more obscurity than those that appertain to this subject.

All the parts described as constituting the nervous system—brain, cerebellum, medulla spinalis, and nerves—are formed of the primary nervous fibre, the nature of which has been already described. The *neurine* or substance of which they are constituted is soft and pulpy; but the consistence varies in different portions, and, in the whole, at different ages. In the fœtus it is almost fluid; in youth of greater firmness; and in the adult still more so. This softness of structure in the encephalon of the fœtus is by no means inutile. It admits of the pressure, which takes place, to a greater or less extent in all cases of parturition, whilst the head is passing through the pelvis, without the child sustaining any injury. On examining, however, the consistence of different brains, it is necessary to inquire into the period that has elapsed since the death of the individual, as the brain loses its firmness by being kept; and ultimately becomes semi-fluid. It is likewise rendered fluid by disease, constituting *ramollissement du cerveau* or *mollescence of the brain*, to which the attention of pathologists has been directed of comparatively late years, but without much important advantage to science.

When the encephalon is fresh, it has a faint, spermatic, and somewhat tenacious smell. This, according to M. Chaussier, has persisted for years in brains that have been dried.

Neurine has been subjected to analysis by M. Vauquelin,[1] and found to contain, water, 80·00; white fatty matter, 4·53; red fatty matter, called *cerebrin*, 0·70; osmazome, 1·12; albumen, 7·00; phosphorus, 1·50; sulphur, and acid phosphates of potassa, lime, and magnesia, 5·15. M. Couerbe's analysis of that of the brain[2] gives, 1. A pulverulent yellow fat, *stearconote;* 2. An elastic yellow fat, *cerancephalote;* 3. A reddish-yellow oil, *eleancephol;* 4. A white fatty matter, *cerebrote*, the *white fatty matter* of Vauquelin, the *myelocone* of Kühn; 5. Cerebral cholesterin—*cholesterote;* and the salts found by Vauquelin,—lactic acid, sulphur, and phosphorus, which form a part of the fats above mentioned.[3] In the spinal cord, there is more fatty matter, and less osmazome, albumen, and water. In the nerves, albumen predominates, and fatty matters are less in quantity. Researches by M. Lassaigne show, that water constitutes $\frac{7}{10}$ths of the nerves; and $\frac{8}{10}$ths of the brain; whilst the proportion of albumen in the former is $\frac{22}{100}$ths; in the latter, $\frac{7}{100}$ths. He found the neurine of different parts of the brain to be composed as follows:

[1] Annales de Chim., lxxxi. 37; and Annals of Philosophy, i. 332.

[2] Annales de Chimie et de Physique, lvi. 160.

[3] For John's Analysis of the white and gray cerebral matter, see Journal de Chimie Médicale, Août, 1835. See, also, Simon's Medical Chemistry, p. 81, Lond., 1845; or Amer. edit., Philad., 1846.

	The whole Brain.	White portion.	Gray portion.
Water,	77·0	73·0	85·0
Albumen,	9·6	9·9	7·5
White fatty matter,	7·2	13·9	1·0
Red fatty matter,	3·1	0·9	3·7
Osmazome, lactic acid, and salts,	2·0	1·0	1·4
Earthy phosphate,	1·1	1·3	1·2
	100·0	100·0	100·0[1]

M. Raspail[2] has pointed out two other differences. *First*, when a nerve is left upon a plate of glass in dry air, it becomes dry, without putrefying, whilst cerebral neurine putrefies in twenty-four hours; and *secondly*, the dried nerve has all the physical characters of the corneous substances,—nails, hair, and other analogous bodies; and in their chemical relations, these bodies do not differ sufficiently to repel the analogy. Neither the chemical analysis of neurine, nor inquiry into its minute structure by the aid of the microscope, has, however, thrown light upon the wonderful functions executed by this elevated part of the organism.

It would seem, that neurine is, in composition, intermediate between fat and the compounds of protein; it contains nitrogen, which is not present in fats, but in smaller proportion than in protein; and, on the other hand, it is much richer in carbon than protein or its compounds. Phosphorus, too, is an essential ingredient. According to researches by M. Frémy, there is in cerebral neurine a peculiar acid, analogous to the fatty acids, which he calls *cerebric acid*, and which contains nitrogen and phosphorus; this is mixed with an albuminous substance; with an oily acid—*oleo-phosphoric;* with cholesterin; and with small quantities of olein and margarin, and oleic and margaric acids.[3]

As Lehmann,[4] however, has remarked, the analysis of the nervous tissue is still very imperfect.[5]

To the naked eye, neurine appears under two forms;—the one gray and of a softer consistence; the other white, and more compact. The former is called the *vesicular*, *gray*, *cortical*, *cineritious*, or *pulpy* substance; the latter, the *tubular*, *white*, *medullary*, or *fibrous*, called "tubular" in consequence of its consisting of tubes of great minuteness, which are filled with a kind of granular albuminous pith that can be squeezed from them,—a view adopted by most histologists. Dr. James Stark has,[6] however, affirmed, as the result of his examination, —and Mulder and Donders accord with him—that the matter which fills the tubes is of an oily nature, differing, in no essential respect, from butter or soft fat, and remaining of a fluid consistence during the

[1] Journal de Chim. Médic.; and Pharmaceutisches Central Blatt, Nov. 19, 1836, S. 765.

[2] Chimie Organique, p. 217, Paris, 1833.

[3] Journ. des Connais. Méd.-Chir., Jan., 1841; also Turner and Liebig's Chemistry, 7th edit., p. 1195, Lond., 1842.

[4] Lehrbuch der Physiologischen Chemie, iii. 123, Leipzig, 1851; and Amer. edit. of Dr. Day's translation, by Dr. Robert E. Rogers, ii. 266, Philad., 1855.

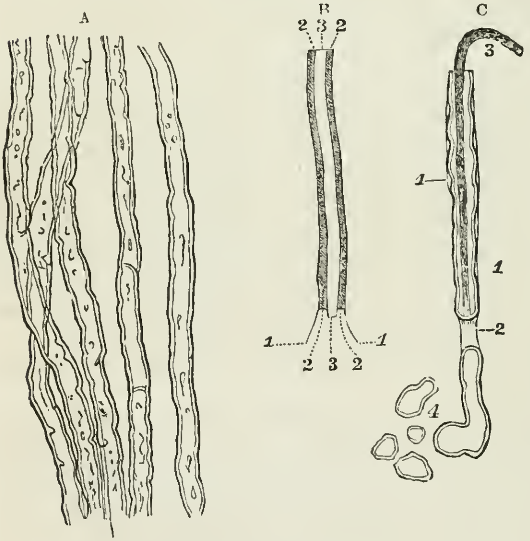
[5] For the recent analyses of the neurine of man and the mammalia, by Von Bibra, Schlossberger, and others, see an excellent resumé by Dr. Day, in Brit. and For. Med.-Chir. Rev., July, 1855, p. 223.

[6] Proceedings of the Royal Society, No. 56, Lond., 1843.

life of the animal, or whilst it retains its natural temperature; but becoming granular or solid when the animal dies.

Lehmann[1] is of opinion, that although it is difficult to obtain direct proof from microscopical observations, or rather to form a judgment from them, the descriptions of the alterations experienced by the medulla or nerve-pulp on the addition of different reagents—in becoming coarsely or finely granular or crystalline—seem to indicate, that the nerve-pulp contains a soluble protein substance, in the closest admixture with a fat dissolved by easily decomposable soaps, and that the visibility of the pulp is owing less to the coagulation of this albuminous body than to the separation of the fat from the decomposing soaps and the albuminous substance. The pith that fills the tubes or the axis cylinder he regards as a protein substance presenting many resemblances to the substance of the muscular fibrils—syntonin; and he dissents, therefore, from the view of those—as Mulder and Donders—who regard it to be composed of fat, or at all events of a very fatty substance.

Fig. 207.



Tubular Nerve-fibres.

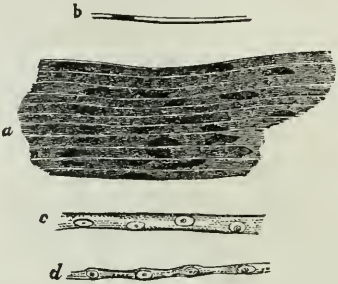
A. Tubular nerve-fibres, showing the sinuous outline and double contours.
B. Diagram to show the parts of a tubular fibre, viz.: 1, 1. *Membranous tube.* 2, 2. *White substance* or *medullary sheath.* 3. *Axis* or *primitive band.*
C. Figure (imaginary) intended to represent the appearances occasionally seen in the tubular fibres. 1, 1. Membrane of the tube seen at parts where the white substance has separated from it. 2. A part where the white substance is interrupted. 3. Axis projecting beyond the broken end of the tube. 4. Part of the contents of the tube escaped.

The tubular nervous matter, wherever it is found, seems to consist of fibres, which have a definite arrangement. Two kinds of primitive fibre, according to the researches of Messrs. Todd and Bowman,[2] are present in the nervous system, which they distinguish as the *tubular fibre* or *nerve tube*, and the *gelatinous fibre*,—the former infinitely the more numerous, and the latter found chiefly in the sympathetic system. The tubular fibres vary in diameter from $\frac{1}{1600}$th even to $\frac{1}{10000}$th of an inch; but their average width is from $\frac{1}{2000}$th to $\frac{1}{4000}$th of an inch. The gelatinous fibre is devoid of the whiteness that characterizes the tubular fibre; and the gray colour of certain nerves, it has been thought, is dependent chiefly

[1] Op. cit.
[2] Dr. Todd, Art. Nervous Centres, in Cyclop. of Anat. and Phys., Pt. xxvi., p. 707; and The Physiological Anatomy and Physiology of Man, p. 208, London, 1845.

upon the presence of a large proportion of gelatinous fibres. Hence they have been sometimes termed *gray fibres.* These are in general smaller than the tubular fibres,—their average diameter ranging between the $\frac{1}{6000}$th and the $\frac{1}{4000}$th of an inch.[1]

Fig. 208.



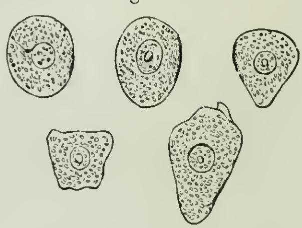
Gelatinous Nerve-fibres.

a and *b* magnified 340 diameters, after Hannover; *c* and *d* after Remak.

The central portion of each nerve-fibre differs from the peripheral: the former has been termed by Rosenthal and Purkinje the *axis-cylinder;* the latter is the *medullary* or *white substance of Schwann*, and to it the white colour of the cerebro-spinal nerves is chiefly due.

The researches of histologists have shown that *vesicles* or cells containing nuclei and nucleoli, and called also *nerve corpuscles* and *globules* and *ganglion corpuscles* and *globules*, are the essential elements of gray or vesicular matter. These are found in the nervous centres, mingled with nerve-fibres, and imbedded in a dimly shaded or granular substance. They give to the ganglia and to certain parts of the brain and spinal cord the peculiar grayish or reddish-gray appearance by which they are characterized. They are large nucleated cells, filled with a finely granular material; some of which is often dark, like pigment; —the nucleus, which is vesicular, containing a nucleolus. The marginal figure (Fig. 209) represents some that have a regular outline. Others, as in Fig. 210, are *caudate* or *stellate*, and have tubular processes issuing from them, filled with the same kind of granular matter as is contained in the corpuscle.

Fig. 209.



Ganglion Corpuscles.

In one a second nucleus is visible. The nucleus of several contains one or two nucleoli.

The gray substance is not always at the exterior, nor the medullary in the interior. In the medulla spinalis, their situation is the reverse of what it is in the brain. In the invertebrata, the gray matter forms the nuclei of the ganglia, which are the centres of the nervous system; and the true spinal system, which occupies the interior of the spinal cord, has been regarded as a chain of similar ganglia. It is the organ, as already shown, of the spinal excito-motory nervous function. Ruysch considered, that the gray portion owes its colour to the bloodvessels that enter it;[2] and, in this opinion, Haller, Adelon,[3] and others,[4] concur; but this is not probable, and it has not been by any means demonstrated, nor has the

[1] See on the disputes in regard to the two sets of nerve fibres, and especially on the so called fibres of Remak or gelatinous fibres, Dr. J. Drummond, Art. Sympathetic Nerve, in Cyclop. of Anat. and Physiol., Pt. xlvii. p. 433, London, August, 1855.

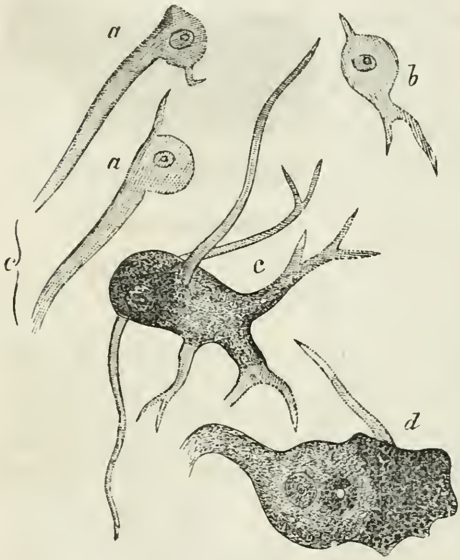
[2] Oper., Amstel., 1727.

[3] Physiologie de l'Homme, 2de édit., i. 208, Paris, 1829.

[4] Carpenter, Human Physiology, p. 81, Lond., 1842.

nature of the pigmental matter been detected.[1] The medullary portion has the appearance of being fibrous; and it has been so regarded by Leeuenhoek,[2] Vieussens, Steno, and Gall and Spurzheim.[3] Malpighi[4] believed the gray cortical substance to be an assemblage of small follicles, intended to secrete the nervous fluid; and the white medullary substance to be composed of the excretory vessels of these follicles; and an analogous view is entertained by many physiologists of the present day,—the gray matter at least being regarded as the generator of the nervous influence; the white matter as chiefly concerned in its conduction. Gall and Spurzheim conjecture, that the use of the gray matter is to be the source or nourisher of the white fibres. The facts, on which they support their view, are, that the nerves appear to be enlarged when they pass through a mass of gray matter, and that masses of this substance are deposited in all parts of the spinal cord where it sends out nerves; but Tiedemann[5] has remarked, that in the fœtus the medullary is developed before the cortical portion, and he conceives the use of the latter to be —to convey arterial blood, which may be needed by the medullary portion for the due execution of its functions. After all, however, it must be admitted with Dr. Allen Thomson,[6] that the general conclusion deducible from all the facts would seem to be, that whilst the gray fibres predominate in the organic or sympathetic nerves, and the tubular fibres in the cerebro-spinal nerves, these two elements are mixed, in various proportions, in the great divisions of the nervous system; and that, therefore, these divisions, although, in a great measure, structurally different, are not altogether distinct from, or independent of, each other. "But"—he properly adds—"in regard to the whole subject of the structures and nature of the different varieties of the nerv-

Fig. 210.



Stellate or Caudate Nerve Corpuscles.

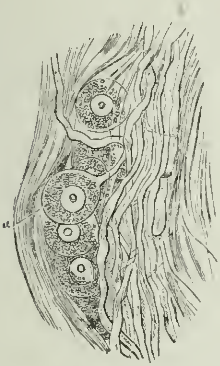
a, a. From the deeper part of the gray matter of the convolutions of the cerebellum. The larger processes are directed towards the surface of the organ. *b.* Another from the cerebellum. *c, d.* Others from the post-horn of gray matter of the dorsal region of the cord. These contain pigment, which surrounds the nucleus in *c.* In all the specimens the processes are more or less broken. Magnified 200 diameters.

[1] Todd, Cyclop. of Anat. and Physiol., Pt. xxv. p. 647, Lond., 1844.
[2] Philos. Transact., 1677, p. 899.
[3] Recherches sur le Système Nerveux en général, et sur celui du Cerveau en particulier, avec figures, Paris, 1809.
[4] Oper. Malpighii, and Mangeti Bibl. Anat., i. 321.
[5] Anatomie und Bildungsgeschichte des Gehirns, mit Tafeln, Nürnberg, 1816.
[6] Outlines of Physiology, Pt. i. p. 155, Edinb., 1848.

ous texture, it is unquestionable that much still remains to be ascertained by laborious investigation."

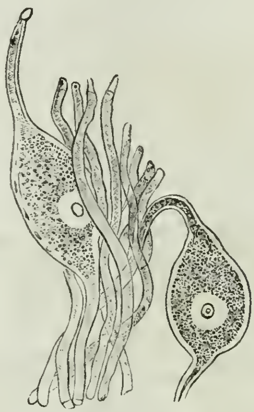
Of the mode in which the tubular neurine communicates with the

Fig. 211.



Microscopic Ganglion from Heart of Frog. Unipolar Ganglionic Cell.

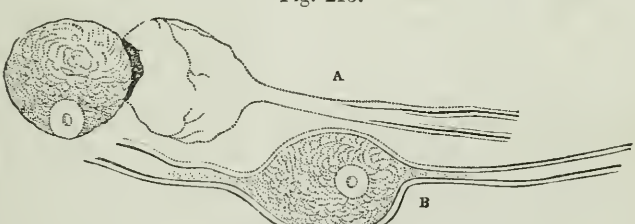
Fig. 212.



Bipolar Ganglionic Cells and Nerve-fibres from ganglion of 5th Pair in Lamprey.

vesicular we know nothing, as yet, that is very definite; that a direct communication must exist appears to be evident. Histologists have

Fig. 213.



Connection between nerve-fibres and nerve corpuscles; from the roots of a spinal nerve of the ray.

A. A nerve-corpuscle, escaped by pressure from the capsule formed around it by the dilated sheath of the nerve-tubule; it shows also the gradual disappearance of the outer portion of the substance of the nerve as it comes into relation with the corpuscles. B. A nerve-corpuscle inclosed within a dilated portion of the sheath of a nerve: part of the granular material of the corpuscle is continuous with the central substance of the nerve in the course of which it is inserted.

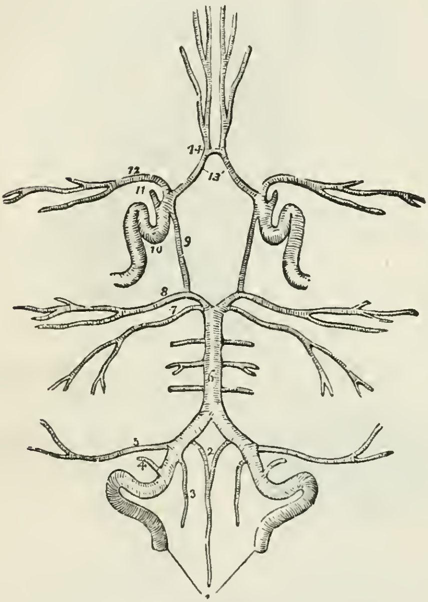
detected it, and it has been noticed, that a vesicle or cell gives off at times, a single prolongation, in which case the ganglionic cell is termed—unipolar; whilst at others, a ganglion cell seems to be contained in a nerve-tube, having each of its extremities prolonged into a fibre or tubule, when the cell is termed—bipolar. The former is said to be more common in man and the higher vertebrata,—the latter in fishes. In certain parts of the nervous centres of man, stellate ganglionic cells send out radiating prolongations, some of which have been observed communicating with the axis cylinder of nerve tubes.[1] Bidder noticed the transition of primitive fibre cells of the roots of the spinal nerves, as well as the longitudinal fibres of the white substance

[1] Ecker, in Carpenter's Principles of Human Physiology, Amer. edit., p. 431, Philad., 1855.

into cells of the gray, in great abundance.[1] Vesicles or corpuscles are seen, however, that do not seem to be immediately connected with nerves.[2]

Sir Charles Bell[3] affirms, that he has found, at different times, all the internal parts of the brain diseased, without loss of sense; but he has never seen disease general on the surface of the hemispheres without derangement or oppression of mind during the patient's life; and hence he concludes, that the vesicular matter of the brain is the seat of the intellect, and the tubular of the subservient parts.[4] A similar use has been ascribed to the vesicular portion, from pathological observations, by MM. Foville and Pinel Grandchamp.[5] This view would afford considerable support to the opinions of Gall, Spurzheim, and others, who consider the organs of the cerebral faculties to be constituted of expansions of the columns of the spinal marrow and medulla oblongata, and to terminate by radiating fibres on the periphery of the brain; as well as to those of M. Desmoulins,[6] and others who regard the convolutions as the seat of the mind. We have, however, cases on record, that signally conflict with this view of the subject; in which the cortical substance has been destroyed, and yet the moral and intellectual manifestations have been little, if at all, injured. Many years ago, the author dissected the brain of an individual of rank in the British army of India, in the anterior lobes of which neither medullary nor cortical portion could be distinguished,—both one and the other appearing to be broken down into a semi-puru-

Fig. 214.



Circle of Willis.

1. Vertebral arteries. 2. Two anterior spinal branches uniting to form a single vessel. 3. One of the posterior spinal arteries. 4. Posterior meningeal. 5. Inferior cerebellar. 6. Basilar artery giving off its transverse branches to either side. 7. Superior cerebellar artery. 8. Posterior cerebral. 9. Posterior communicating branch of the internal carotid. 10. Internal carotid, showing the curvatures it makes within the skull. 11. Ophthalmic artery divided across. 12. Middle cerebral artery. 13. Anterior cerebral arteries connected by, 14. Anterior communicating artery.

[1] Dr. J. W. Ogle, Report of Micrology, in Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 525.

[2] See, on all this subject, Kölliker, Mikroskopische Anatomie, ii. 508, Leipzic, 1850, or Amer. edit. of Sydenham Society's edition of his Manual of Histology, p. 356, Philadelphia, 1854; and Drummond, Cyclop. of Anat. and Physiol., loc. cit.

[3] Anatomy and Physiology, 5th Amer. edit., by J. D. Godman, p. 29, New York, 1827.

[4] See two interesting pathological cases, confirming this view of the function of the gray matter, by Dr. Cowan, in Provincial Medical and Surgical Journal, April 16, 1845.

[5] Sur le Système Nerveux, Paris, 1820.

[6] Anatomie des Systèmes Nerveux des Animaux à Vertèbres, p. 599, Paris, 1825.

lent, amorphous substance; yet the intellectual faculties had been nearly unimpaired, although the morbid process must have been of some duration.

The encephalon affords many striking instances of the different effects produced by sudden, and by gradual interference with its functions. Whilst a depressed portion of bone or an extravasation of blood may suddenly give rise to the abolition of the intellectual and moral faculties, gradual compression by a tumour may scarcely interfere with any of its manifestations.

The circulation of blood in the encephalon requires notice. The arteries are four in number,—two *internal carotids*, and two *vertebrals:* to these may be added the *spinal* or *middle artery of the dura mater*,—*arteria meningœa media*. The carotid arteries enter the head through the carotid canals, which open on each side of the sella turcica, or of the chiasma of the optic nerves. The vertebral arteries enter the head through the foramen magnum of the occipital bone; unite on the medulla oblongata to form the basilary artery, which passes forward along the middle of the pons Varolii; and, at the anterior part of the pons, gives off lateral branches, which inosculate with corresponding branches of the carotids, and form a kind of circle at the base of the brain, which has been called *circulus arteriosus* of Willis. The passage of the bloodvessels is extremely tortuous, so that the blood does not enter the brain with great impetus; and they become capillary before they penetrate the organ,—an arrangement of importance, when we regard the large amount of blood sent to it. This has been estimated as high as one-eighth of the whole fluid transmitted from the heart. The amount does not admit of accurate appreciation, but it is considerable. It of course varies according to circumstances. In hypertrophy of the heart, the quantity is sometimes increased; as well as in ordinary cases of what are called *determinations* of blood to the head. Here, too large an amount is sent by the arterial vessels; but an equal accumulation may occur, if the return of the blood from the head by the veins be in any manner impeded,—as when we stoop, or compress the veins of the neck by a tight cravat, or by keeping the head turned for a length of time. Congestion or accumulation of blood may therefore arise from very different causes.

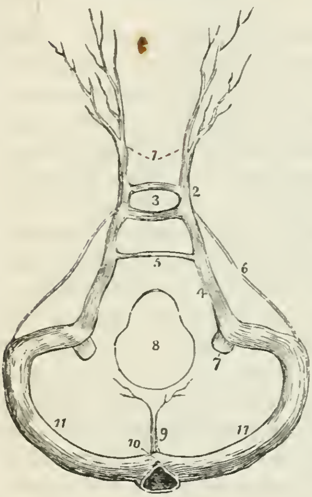
Sir Astley Cooper[1] found by experiment, that the vertebral arteries are more important vessels as regards the encephalon and its functions in certain animals, as the rabbit, than the carotids. The nervous power is lessened by tying them; and, in his experiments, the animals did not, in any case, survive the operation more than a fortnight. In the dog, he tied the carotids with little effect, but the ligature of the vertebrals had a great influence. The effect of the operation was to render the breathing immediately difficult and laborious; owing, in Sir Astley's opinion, to the supply of blood to the phrenic nerves, and the whole *tractus respiratorius* of Sir Charles Bell, being cut off. The animal became dull, and indisposed to make use of exertion; or to take food. Compression of the carotids and the vertebrals at the same moment, in the rabbit, destroyed the nervous functions immediately. This was effected by the application of the thumbs to both sides of the neck, the

[1] Guy's Hospital Reports, i. 472, London, 1836.

trachea remaining free from pressure. Respiration ceased entirely, with the exception of a few convulsive gasps. The same fact was evinced in a clearer and more satisfactory manner by the application of ligatures to the four vessels, all of which were tightened at the same instant. Stoppage of respiration and death immediately ensued.

The cerebral, like other arteries, are accompanied by branches of the great sympathetic. The researches of of Purkinje,[1] Volkmann,[2] and Rainey,[3] have shown the existence of a large number of nerves in connection with the encephalic and spinal arachnoid. They do not seem to communicate with the roots of the spinal nerves, but belong exclusively to the sympathetic.[4] The encephalic veins are disposed as already described, terminating in *sinuses* formed by the dura mater, and conveying their blood to the heart by means of the lateral sinuses and internal jugulars; but of the peculiarities of the circulation in the encephalon, mention will be made in the appropriate place. No lymphatic vessels have been detected in the encephalon; yet, that absorbents exist there is proved by the dissection of apoplectic and paralytic individuals. In these cases, when blood has been effused, the red particles are gradually taken up, with a portion of the fibrinous part of the blood, leaving a cavity called an *apoplectic cell*, which is at the same time the evidence of previous extravasation and subsequent absorption.

Fig. 215.

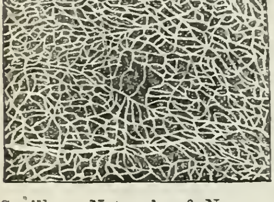


Sinuses of the Base of the Skull.

1. Ophthalmic veins. 2. Cavernous sinus of one side. 3. Circular sinus: the figure occupies the position of the pituitary gland in the sella turcica. 4. Inferior petrosal sinus. 5. Transverse or anterior occipital sinus. 6. Superior petrosal sinus. 7. Internal jugular vein. 8. Foramen magnum. 9. Occipital sinuses. 10. Torcular Herophili. 11, 11. Lateral sinuses.

The whole of the nervous system is well supplied with bloodvessels. In the vesicular neurine of the nervous centres, the capillaries surround the ganglion cells or globules; and in the tubular they pass between the nerve-tubes, being connected at intervals by transverse branches.

Fig. 216.



Capillary Network of Nervous Centres.

When the skull of the new-born infant, which, at the fontanelles, consists of membrane only—or the head of any one who has received an injury, that exposes the brain—is examined, two distinct movements are perceptible. One, which is generally obscure, is synchronous with the pulsation of the heart and

[1] Müller's Archiv. für Anatomie, p. 281, Berlin, 1845.

[2] Art. Nervenphysiologie, Wagner's Handwörterbuch der Physiologie, 10te Lieferung, S. 494, Braunschweig, 1845.

[3] Medico-Chirurgical Transactions for the year 1845.

[4] Brinton, Art. Serous and Synovial Membranes, in Cyclop. of Anat. and Physiol., Pt. xxxiv. p. 525, Lond., Jan., 1849.

arteries; the other, much more apparent, is connected with respiration, the organ seeming to sink at the time of inspiration, and to rise during expiration. This phenomenon is not confined to the cerebrum, but exists likewise in the cerebellum and spinal marrow. The motion of the encephalon, synchronous with that of the heart, admits of easy explanation. It is owing to the pulsation of the circle of arteries at the base of the brain elevating the organ at each systole of the heart. The other movement is not so readily intelligible. It has been attributed to the resistance, experienced by the blood in its passage through the lungs during expiration, owing to which an accumulation of blood takes place in the right side of the heart; this extends to the veins and to the cerebral sinuses, and an augmentation of bulk is thus occasioned. It has been elsewhere remarked, that one of the forces conceived to propel the blood along the vessels is atmospheric pressure. According to that view, the sinking down of the brain during inspiration is explicable; the blood is rapidly drawn to the heart; the quantity in the veins is consequently diminished; and sinking of the brain succeeds.

On dissection, we find that the encephalon fills the cavity of the cranium; during life, therefore, it must be pressed upon, more or less, by the blood in the vessels, and by the serous fluid exhaled by the pia mater into the subarachnoid tissue. Thence it penetrates into the ventricles,—according to M. Magendie, at the lower end of the fourth ventricle, at the *calamus scriptorius*. The quantity varies according to the age and size of the patient, and usually bears an inverse proportion to the size of the encephalon. It is seldom, however, less than two ounces, and often amounts to five. M. Magendie is of opinion, that the fluid is secreted by the pia mater, and states, that it may be seen transuding from it in the living animal. The results of chemical analysis appear to show, that it differs from mere serum. It is obviously, however, almost impracticable—if not wholly so—to separate the consideration of this fluid from that met with in the cavity of the arachnoid.

The spinal marrow does not, as we have seen, fill the vertebral canal; the cephalo-spinal fluid exerts upon it the necessary pressure; added to which, the pia mater seems to press more upon this organ than upon the rest of the cerebro-spinal system. A certain degree of pressure appears, indeed, necessary for the due performance of its functions; and if this be either suddenly and considerably augmented, or diminished, derangement of function is the result. M. Magendie,[1] however, asserts, that he has known animals, from which the fluid had been removed, survive without any sensible derangement of the nervous functions. It is this fluid, which is drawn off by the surgeon when he punctures in a case of spina bifida.

When the brain is examined in the living body, it exhibits properties, which, some years ago, it would have been esteemed the height of hardihood and ignorance to ascribe to it. The opinion has universally prevailed, that all nerves are exquisitely sensible. Many opportuni-

[1] Précis Él´mentaire, seconde édit., i. 192; and Recherches Physiologiques et Cliniques sur le Liquide Céphalo-rachidien ou Cérébro spinal, Paris, 1842. Dr. Todd, Cyclopædia of Anatomy and Physiology, Pt. xxv. p. 639, London, 1844; and Foltz, Schmidt's Jahrb. xxxvi. 292, and Brit. and For. Med.-Chir. Rev., Jan., 1856, p. 234.

ties will occur for showing, that this sentiment is not founded on fact; even the encephalon itself,—the organ in which perception takes place,—is insensible, in the common acceptation of the term; that is, we may prick, lacerate, cut, and even cauterize it, yet no painful impression will be produced. Experiment leaves no doubt regarding the truth of this, and we find the fact frequently confirmed by pathological cases. Portions of brain may be discharged from a wound in the skull, and yet no pain be evinced. In his "Anatomy and Physiology," Sir C. Bell[1] remarks, that he cannot resist stating, that on the morning on which he was writing, he had had his finger deep in the anterior lobes of the brain; when the patient, being at the time acutely sensible, and capable of expressing himself, complained only of the integument. A pistol-ball had passed through the head, and Sir Charles, having ascertained, that it had penetrated the dura mater by forcing his finger into the wound, trephined on the opposite side of the head, and extracted it.

By the experiments, instituted by MM. Magendie,[2] Flourens and others, it has been shown, that an animal may live days, and even weeks, after the hemispheres have been removed; nay, that in certain animals, as reptiles, no change is produced in their habitudes by such abstraction. They move about as if unhurt. Injuries of the surface of the cerebellum exhibit, that it also is not sensible; but deeper wounds, and especially such as interest the peduncles, have singular results,—to be mentioned hereafter. The spinal cord is not exactly circumstanced in this manner. Its sensibility is exquisite on the posterior surface; much less on the anterior, and almost null at the centre. Considerable sensibility is also found within, and at the sides of, the fourth ventricle; but this diminishes as we proceed towards the anterior part of the medulla oblongata, and is very feeble in the tubercula quadrigemina of the mammalia.

It has been shown, that the spinal nerves, by means of their posterior roots, convey general sensibility to the parts to which they are distributed. But there are other nerves, which, like the brain, are themselves entirely devoid of general sensibility. This has given occasion to a distinction of nerves into those of *general* and of *special* sensibility. Of nerves, which must be considered insensible or devoid of general sensibility, we may instance the optic, olfactory, and auditory. Each of these has, however, a *special sensibility;* and although it may exhibit no pain when irritated, it is capable of being impressed by appropriate stimuli—by light, in the case of the optic nerve; by odours, in that of the olfactory; and by sound, in that of the auditory. Yet we shall find, that most of the nerves of special sensibility seem to require the influence of a nerve of general sensibility,—the fifth pair.

Many nerves appear devoid of sensibility, as the third, fourth, and sixth pairs; the portio dura of the seventh; the ninth pair of encephalic nerves; and, as has been shown, all the anterior roots of the spinal nerves.

The parts of the encephalon, concerned in muscular motion, will fall under consideration hereafter.

[1] Fifth Amer. edit. by J. D. Godman, ii. 6, New York, 1827.
[2] Précis Elémentaire, i. 325.

2. PHYSIOLOGY OF SENSIBILITY.

Animal sensibility we have defined to be—the function by which we experience feeling, or have the perception of an impression. It includes two great sets of phenomena; the *sensations*, properly so called, and the *intellectual* and *moral manifestations*. These we shall investigate in succession.

a. *Sensations.*

A sensation is the perception of an impression made on a living tissue;—or, in the language of Gall, it is the perception of an irritation. By the sensations we receive a knowledge of what is passing within or without the body; and, in this way, our notions or ideas of them are obtained. When these ideas are reflected upon, and compared with each other, we exert *thought* and *judgment;* and they can be recalled with more or less vividness and accuracy by the exercise of *memory.*

The sensations are numerous, but they may all be comprised in two divisions,—the *external* and the *internal.* Vision and audition afford us examples of the former, in which the impression made upon the organ is external to the part impressed. Hunger and thirst are instances of the latter, the cause being internal, necessary, and depending upon influences seated in the economy itself. Let us endeavour to discover in what they resemble each other.

In the first place, every sensation, whatever may be its nature,—external, or internal,—requires the intervention of the encephalon. The distant organ—as the eye or ear—may receive the impression, but it is not until this impression has been communicated to the encephalon, that sensation is effected. The proofs of this are easy and satisfactory. If we cut the nerve proceeding to any sensible part, put a ligature around it, or compress it in any manner,—it matters not that the object, which ordinarily excites a sensible impression, is applied to the part,—no sensation is experienced. Again, if the brain, the organ of perception, be prevented in any way from acting, it matters not that the part impressed, and the nerve communicating with it, are in a condition necessary for the due performance of the function, sensation is not effected. We see this in numerous instances. In pressure on the brain, occasioned by fracture of the skull; or in apoplexy, a disease generally dependent upon pressure, we find all sensation, all mental manifestation, lost; and they are not regained until the compressing cause has been removed. The same thing occurs if the brain be stupefied by opium; and, to a less degree, in sleep, or when the brain is engaged in intellectual meditations. Who has not found, that in a state of reverie or brown study, he has succeeded in threading his way through a crowded street, carefully avoiding every obstacle, yet so little impressed by the objects around as not to retain the slightest recollection of them! On the other hand, how vivid are the sensations when attention is directed to them! Again, we have numerous cases in which the brain itself engenders the sensation, as in dreams, and in insanity. In the former, we see, hear, speak, use every one of our senses apparently; yet there has been no impression from without. Although we may behold in our dreams the figure of a friend long since dead, there can obviously be no impression made on the retina from without.[1] Such are called *subjective sensations*, to distinguish them from those caused by impressions made by objects on the peripheral extremities of the nerves of sense, and hence termed *objective sensations.*

The whole history of spectral illusions, morbid hallucinations, and maniacal phantasies, is to be accounted for in this manner. Whether, in such cases, the brain reacts upon the nerves of sense, and produces an impression upon them from within, similar to what they experience from without during the production of a sensation, will form a subject for future inquiry. Pathology also affords several instances where the brain engenders the sensation, most of which are precursory signs of cerebral derangement. The appearance of spots flying before the eyes, of spangles, depravations of vision, hearing, &c., and a sense of numbness in the extremities, are referable to this cause; as well as the singular fact well known to the operative surgeon, that pain is often felt in the stump of a limb, months after it has been removed from the body.

These facts prove, that every sensation, although referred to some organ, must be perfected in the brain. The impression is made upon the nerve of the part, but the appreciation takes place in the common sensorium.

There are few organs which could be regarded insensible, were we aware of the precise circumstances under which their sensibility is elicited. The old doctrine—as old indeed as Hippocrates[2]—was, that the tendons and other membranous parts are among the most sensible of the body. This opinion was implicitly credited by Boerhaave, and his follower Van Swieten;[3] and in many cases had a decided influence on surgical practice more especially. As the bladder consists principally of membrane, it was agreed for ages by lithotomists, that it would be improper to cut or divide it; and, therefore, to extract the stone dilating instruments were used, which caused the most painful lacerations of the parts. Haller[4] considered tendons, ligaments, periosteum, bones, meninges of the brain, different serous membranes, arteries and veins, entirely insensible; yet we know, that they are exquisitely sensible when attacked with inflammation. One of the most painful affections to which man is liable is the variety of whitlow that implicates the periosteum; and in all affections of the bone which inflame or press forcibly upon that membrane, there is excessive sensibility. It would appear, that the possession of vessels or vascularity is a necessary condition of the sensibility of any tissue.

Many parts, too, are affected by special irritants; and, after they have appeared insensible to a multitude of agents, show great sensibility when a particular irritant is applied. Bichat endeavoured to elicit the sensibility of ligaments in a thousand ways, without success; but when he subjected them to distension or twisting, they immediately gave evidence of it. It is obvious, that before we determine that a part is insensible, it must have been submitted to every kind of irritation.

[1] Adelon, art. Encéphale (Physiologie), in Dict. de Méd., vii. 514, Paris, 1823; and Physiol. de l'Homme, tom. i. p. 239, 2de édit., Paris, 1829.

[2] Foësii Œconom. Hippocr. "Νεῦρον." [3] Aphorism. 164 and 165, and Comment.

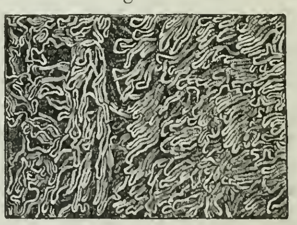
[4] Oper. Minor., tom. i.

M. Adelon affirms, that there is no part but what may become painful by disease. From this assertion the cuticle might be excepted. If we are right, indeed, in our view of its origin and uses, as described hereafter, sensibility would be of no advantage to it; but the contrary. In the present state, then, of our knowledge, we are justified in asserting, that bones, cartilages, and membranes are not sensible to ordinary external irritants, when in a state of health,—or in other words, that we are not aware of the irritants, which are adapted to elicit their sensibility.

That sensibility is due to the nerves distributed to a part is so generally admitted as not to require comment. Dr. Todd[1] has affirmed, that the anatomical condition necessary for the developement of the greater or less sensibility of an organ or tissue is the distribution in it of a greater or less number of sensitive nerves; and that the anatomist can determine the degree to which this property is enjoyed by any tissue or organ by the amount of nervous supply, which his research discloses. It may well be doubted, however, whether such sensibility be by any means in proportion to the number of nerves received by a part. Nay, some parts are acutely sensible in disease into which nerves cannot be traced. To explain these cases, Reil[2] supposed that each nerve is surrounded at its termination by a nervous atmosphere, by which its action is extended beyond the part in which it is seated. This opinion is a mere creation of the imagination. We have no evidence of any such atmosphere; and it is more philosophical to presume, that the reason we do not discover nerves may be owing to the imperfection of our vision.

We may conclude, that the action of impression occurs in the nerves of the part to which the sensation is referred. As to the mode in which this impression affects them we are ignorant. Microscopic examination of the nerves connected with sensory organs would seem to show, that they come into relation with a substance very analogous to the gray matter of the encephalon, although its elements are somewhat differently arranged. The nervous fibres, too, appear to terminate in close approximation with a vascular plexus; and a granular structure is present, which—as in the vesicular portion of the brain—seems to be intermediate. This point has been regarded as the origin of the afferent fibres; and as the seat of changes made by external impressions.[3]

Fig. 217.



Distribution of Capillaries at the surface of the skin of the finger.

The facts mentioned show, that the action of perception takes place in the encephalon; and that the nerve is merely the conductor of the impression between the part impressed and that organ. If a ligature be put round a nerve, sensation is lost below the ligature; but it is uninjured above it. If two ligatures be applied, sensibility is lost in the portion included between the ligatures; but it is restored if the upper ligature be removed. The spinal marrow is sensible along the whole of its posterior column, but it also acts only as a conductor of

[1] Art. Sensation, Cyclopædia of Anat. and Physiology, pt. xxxiv. p. 511, Jan., 1849.
[2] Exercitat. Anatom. Fascic., i. p. 28; and Archiv. für die Physiologie, B. iii.
[3] Carpenter, Human Physiology, p. 85, Lond., 1842.

the impression. M. Flourens destroyed the spinal cord from below, by slicing it away; and found, that sensibility was gradually extinguished in the parts corresponding to the destroyed medulla, but that the parts above evidently continued to feel. Perception, therefore, occurs in the encephalon; and not in the whole, but in some of its parts. Many physiologists—Haller, Lorry, Rolando, and Flourens[1]—sliced away the brain, and found that the sensations continued until the knife reached the level of the corpora quadrigemina; and, again, it has been found, that if the spinal cord be sliced away from below upwards, the sensations persist until we reach the medulla oblongata. It is, then, between these parts, that we must place the cerebral organs of the senses, and it is with this part of the cephalo-spinal axis, that the nerves of the senses are actually found to communicate. Mr. Lawrence[2] saw a child with no more encephalon than a bulb, which was a continuation of the medulla spinalis, for about an inch above the foramen magnum, and with which all the nerves from the fifth to the ninth pair were connected. The child's breathing and temperature were natural; it discharged urine and fæces; took food, and at first moved very briskly. It lived four days.

If we divide the posterior roots of the spinal nerves and the fifth pair, *general* sensibility is lost; but if we divide the nerves of the senses, we destroy only their functions. We can thus understand why, after decapitation, sensibility may remain for a time in the head. It is instantly destroyed in the trunk, owing to the removal of all communication with the encephalon; but the fifth pair is entire, as well as the nerves of the organs of the senses. Death must of course follow almost instantaneously from loss of blood; but there is doubtless an appreciable interval during which the head may continue to feel; or, in other words, during which the external senses may act.[3] M. Julia Fontanelle[4] has indeed concluded, from a review of all the observations made on this matter, that, contrary to the common opinion, death by the guillotine is one of the most painful; that the pains of decollation are horrible, and endure even until there is an entire extinction of animal heat! It need scarcely be said, that all these inferences are imaginative, and perhaps equally fabulous with the oft-told story of Charlotte Corday scowling at the executioner, after her head was removed from her body by the guillotine; and this conclusion is strongly confirmed by the results of experiments on a robber—who was beheaded with the sword—by Drs. Bischoff, Heerman, and Jolly, who inferred that consciousness must have ceased instantaneously.[5] But if such be the case with man, it most assuredly is not so with the inferior animals. Ample evidence will be afforded hereafter to show, that both sensation and volition may persist, apparently, in the rattle-

[1] Rolando, Saggio sopra la vera Struttura del Cervello, Sassari, 1809; and Flourens, Recherches Expérimentales sur les Propriétés et les Fonctions du Système Nerveux, &c., 2de édit., Paris, 1842.

[2] Medico-Chirurg. Transact., v. 166.

[3] Bérard, Rapports du Physique et du Moral, p. 93, Paris, 1823.

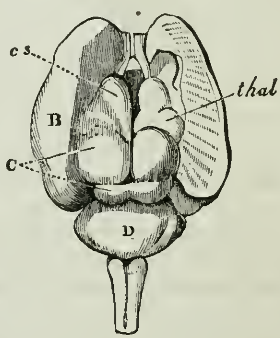
[4] Phœbus, Art. Enthauptung, in Encyclopäd. Wörterb. der Medicin. Wissenchaft. xi. 204, Berlin, 1835.

[5] A condensed account of Dr. Bischoff's Remarks, from Müller's Archiv., by S. L. L. Bigger, is in the Dublin Journal of Medical Science, Sept., 1839, p. 1.

snake and alligator, long after the head has been removed from the body. Singular facts in regard to the latter animal have been recorded by Dr. Leconte,[1] and by Dr. Dowler,[2] of New Orleans.

It has been remarked, that the cerebral hemispheres may be sliced away without abolishing the senses. The experiments of Rolando and Flourens, which have been repeated by M. Magendie, show, however, that the sight is an exception;—that it is lost by their removal. If the right hemisphere be sliced away, the sight of the left eye is lost; and conversely;—one of the facts that prove the decussation of the optic nerves. The experiments of these gentlemen show, that vision, more than the other senses, requires a connection with the organ of the intellectual faculties—the cerebral hemispheres; and this, as M. Magendie has ingeniously remarked, because vision rarely consists in a single impression made by light, but is connected with an intellectual process, by which we judge of the distance, size, shape, &c., of bodies. It has been well suggested and maintained by Dr. Carpenter,[3] that whilst the cerebral ganglia are the organs of the higher intellectual and moral acts; there is a series of ganglia, connected with the reception of impressions from without, which are seated near the base of the brain, and are hence termed by him *sensory ganglia*. As we descend in the animal scale, these ganglia become more marked; whilst the cerebral hemispheres become less and less; until ultimately the animal appears to have its encephalic organs limited almost wholly to those that are concerned in the reception of impressions from without, and the originating of motor impulsions from within. These ganglia are seated at the base of the brain, from the origin of the auditory nerves to those of the olfactory. Dr. Carpenter is disposed to regard the optic thalami as ganglia for the reception of tactile impressions, and the corpora striata as ganglia connected with motion. He esteems them to be, moreover, the centre of consensual or instinctive movements, or of automatic movements involving sensation.

Fig. 218.



Brain of Squirrel, laid open.

The hemispheres, B, drawn to either side to show the subjacent parts. C. The optic lobes. D. Cerebellum. *thal.* Thalamus opticus. *c s.* Corpus striatum.

Having arrived at a knowledge that in man and the upper class of animals perception is effected in a part of the encephalon, our acquaintance with this mysterious process ends. We know not, and we probably never shall know, the action of the brain in accomplishing it. It is certainly not allied to any physical phenomenon; and if we are ever justified in referring functions to the class of *organic* and *vital*, it may be those, that belong to the elevated phenomena, which have to be considered under the head of animal functions. We know them

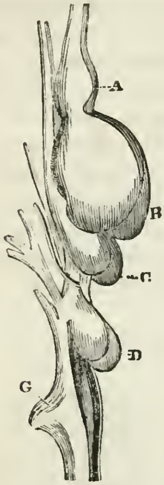
[1] New York Journal of Medicine, for Nov., 1845, p. 335, and Sir Charles Lyell, Travels in North America, Amer. edit., i. 237. New York, 1849.

[2] Contributions to Physiology, New Orleans, 1849, from New Orleans Journal of Medicine.

[3] Principles of Human Physiology, Amer. edit., p. 437, Philad., 1855.

only by their results; yet we are little better acquainted with many topics of physical inquiry;—with the nature of the electric fluid for example.

Fig. 219.



Brain of Turtle.

A. Olfactive ganglia. B. Cerebral hemispheres. C. Optic ganglia. D. Cerebellum.

Fig. 220.

Pike.

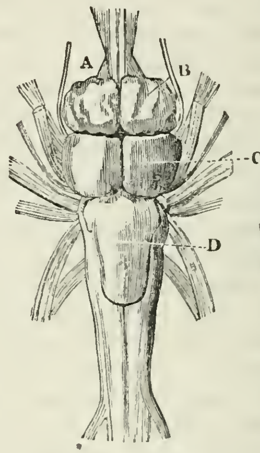
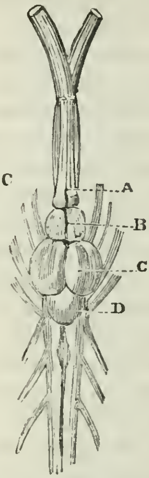


Fig. 221.

Cod.



Brains of Fishes.

A. Olfactive lobes or ganglia. B. Cerebral hemispheres. C. Optic lobes. D. Cerebellum.

The organs, then, that form the media of communication between the parts impressed and the brain, are the nerves and spinal marrow. M. Broussais,[1] indeed, affirmed, that every stimulation capable of causing perception in the brain, runs through the whole of the nervous system of relation; and is repeated in the mucous membranes, whence it is again returned to the centre of perception, which judges of it according to the view of the viscus to which the mucous membrane belongs; and adapts its action as it perceives pleasure or pain.

We are totally unacquainted with the *material* character of the fluid, which passes with the rapidity of lightning along nervous cords; and it is as impossible to describe its mode of transmission, as it is to depict that of the electric fluid along a conducting wire. As in the last case, we are aware of such transmission only by the result. Still, hypotheses, as on every obscure matter of inquiry, have not been wanting.[2] Of these, three are chiefly deserving of notice. The *first*, of greatest antiquity, is, that the brain secretes a subtile fluid, which circulates through the nerves, called *animal spirits*, and which is the medium of communication between the different parts of the nervous system; the *second* regards the nerves as cords, and the transmission as effected by means of the vibrations or oscillations of these cords; whilst the *third* ascribes it to the operation of electricity.

1. The hypotheses of *animal spirits* has prevailed most extensively. It was the doctrine of Hippocrates, Galen, the Arabians, and of most

[1] Traité de Physiologie, &c., Paris, 1822; or translation by Drs. Bell and La Roche, 3d Amer. edit., p. 63, Philad., 1832.

[2] Fletcher's Rudiments of Physiology, P. ii. *b.* p. 68, Edinb., 1836.

of the physicians of the last centuries. Des Cartes[1] adopted it energetically; and was the cause of its more extensive diffusion. The great grounds assigned for the belief were;—*first*, that as the brain receives so much more blood than is necessary for its own nutrition, it must be an organ of secretion; *secondly*, that the nerves seem to be a continuation of the tubular matter of the brain; and it has already been remarked, that Malpighi considered the cortical neurine to be follicular, and the medullary to consist of secretory tubes. It was not unnatural, therefore, to regard the nerves as vessels for the transmission of these spirits. As, however, the animal spirits had never been met with in a tangible shape, ingenuity was largely invoked in surmises regarding their nature; and, generally, opinions settled down into the belief that they were of an ethereal character. For the various views that have been held upon the subject, the reader is referred to Haller,[2] who was himself an ardent believer in their existence, and has wasted much time and space in an unprofitable inquiry into their nature. The truth is, that we have not sufficient evidence, direct or indirect, of the existence of any nervous fluid of the kind described. Allusion has been already made to the views, in regard to the tubular structure of the white neurine, admitted by most observers; Berres[3] affirms that the forms, which the nervous substance assumes under the magnifying glass, can only be compared to those of canals and vesicles; but whether they be hollow he does not attempt to decide. M. Raspail[4] has concluded, that the opinion of their being hollow, and containing a fluid, is unsupported by facts; for although he admits, that M. Bogros succeeded in injecting the nerves with mercury, he thinks that the passage of the metal along them was owing to its having forced its way by gravity. Modern histologists accord with great unanimity as to the tubular structure of the medullary neurine; but we have no reason for considering the brain the organ of any ponderable secretion. Yet the term "animal spirits," although their existence is not now believed, is retained in popular language. We speak of a man who has a great flow of animal spirits, but without regarding the hypothesis whence the expression originated.

The term *nervous fluid* is still used by physiologists. By this, however, they simply mean the medium of communication or of conveyance, by which the nervous influence is carried with the rapidity of lightning from one part of the system to another; but without committing themselves as to its character;—so that, after all, the idea of animal spirits is in part retained, although the term, as applied to the nervous fluid, is generally exploded. Dr. Good[5] directly admits them under the more modern title; Mr. J. W. Earle[6] firmly believes in the existence of a circulation in the nervous system,—and it is not easy to conceive, that the brain does not possess the function of elaborating

[1] Tractatus de Homine, p. 17, Lugd. Bat., 1664.

[2] Elementa Physiologiæ, x. 8.

[3] Oesterreich. Med. Jahrbuch., B. ix., cited in Brit. and Foreign Med. Review, January, 1838, p. 219.

[4] Chimie Organique, p. 218, Paris, 1833.

[5] Study of Medicine, with Notes by S. Cooper, Doane's Amer. edit., vol. ii., in Proem to Class iv. Neurotica, New York, 1835.

[6] New Exposition of the Functions of the Nerves, Part I., London, 1833.

some fluid,—galvanoid or other,—which is the great agent in the nervous function.

2. The hypothesis of vibrations is ancient, but has been by no means as generally admitted as the last. Among the moderns, it has received the support of Condillac,[1] Hartley,[2] Blumenbach,[3] and others; some supposing, that the nervous matter itself is thrown into vibrations; others, that an invisible and subtile ether is diffused through it, which acts the sole or chief part. As the latter is conceived, by many, to be the mode in which electricity is transmitted along conducting wires, it is not liable to the same objections as the former. Simple inspection of a nerve at once exhibits, that it is incapable of being thrown into vibrations. It is soft; never tense; always pressed upon in its course; and, as it consists of filaments destined for very different functions,—sensation, voluntary and involuntary motion, &c.—we cannot conceive how one of these filaments can be thrown into vibration without the effect being extended laterally to others; and great confusion being thus induced. The view of Dr. James Stark,[4] in regard to the structure of the tubes of the nerves, has led him to adopt a modification of the theory of vibrations. Believing, that the matter which fills the tubes is of an oily nature,—and as oily substances are known to be non-conductors of electricity; and farther, as the nerves have been shown by the experiments of Bischoff to be amongst the worst possible conductors of electricity,—he contends, that the nervous energy can be neither electricity nor galvanism, nor any property related to them; and he conceives, that the phenomena are best explained on the hypothesis of undulations or vibrations propagated along the course of the tubes by the oily globules which as before remarked—he considers they contain. Others, as Dr. Brown Séquard[5]—who observed, in experiments on animals, that nerve fibres acted nearly as well when their contents were coagulated as when they were still liquid—are of opinion, that the communication is through the sheath of the nerve,—the membranous tube (Fig. 207).

3. The last hypothesis is of later date,—subsequent to the discoveries in animal electricity. The rapidity with which sensation and volition are communicated along the nerves could not fail to suggest a resemblance to the mode in which the electric and galvanic fluids fly along conducting wires. Yet the great support of the opinion was in the experiments of Dr. Wilson Philip[6] and others, from which it appeared, that if the nerve proceeding to a part be destroyed,—and the secretion, which ordinarily takes place in the part be thus arrested,—the secretion may be restored by causing the galvanic fluid to pass from one divided extremity of the nerve to the other. The experiments, connected with secretion, will be noticed more at length hereafter. It will likewise be shown, that in the effect of galvanism upon

[1] Œuvres, Paris, 1822.
[2] Observations on Man, &c., chap. i. sect. 1. London, 1791.
[3] Institutiones Physiologicæ, § 226.
[4] Proceedings of the Royal Society, No. 56, Lond., 1843.
[5] Medical Examiner, April, 1852, p. 564.
[6] Philosoph. Trans. for 1815, and Lond. Med. Gazette for March 18, and March 25, 1837.

the muscles, there is a like analogy ;—that the muscles may be made to contract for a length of time after the death of the animal, and even when a limb is removed from the body, on the application of the galvanic stimulus; and that comparative anatomy exhibits to us great development of nervous structure in electrical animals, which astonish us by the intensity of the electric shocks they are capable of communicating.

Physiologists of the present day generally, we think, accord with the electrical hypothesis. The late Dr. Young,[1] so celebrated for his knowledge in numerous departments of science, adopted it prior to the interesting experiments of Dr. Philip; and Mr. Abernethy,[2] whilst he is strongly opposing the doctrines of materialism, goes so far as to consider some subtile fluid, not merely as the agent of nervous transmission but as forming the essence of life itself. By putting a ligature, however, around a nervous trunk, its functions, as a conductor of nervous influence, are paralyzed, whilst it is still capable of conveying electricity; and, moreover, when wires are inserted into an exposed nerve, and their opposite extremities are attached to the galvanometer, no movement of the needle has been observed by Person, Müller, Matteucci, Todd and Bowman,[3] and others. Dr. Bostock,[4] too, has remarked, that before the electrical hypothesis can be considered proved, two points must be demonstrated; first, that *every* function of the nervous system may be performed by the substitution of electricity for the action of nerves; and secondly, that *all* nerves admit of this substitution. This is true as concerns the belief in the *identity* of the nervous and electrical fluids; but we have, even now, evidence sufficient to show their similarity; and that we are justified in considering the nervous fluid to be electroid or galvanoid in its nature, emanating from the brain by some action unknown to us, and transmitted to the different parts of the system to supply the expenditure, which must be constantly taking place.

Reil,[5] Senac,[6] Prochaska, Scarpa,[7] and others are of opinion, that the nervous agency is generated throughout the nervous system; and that every part derives sensation and motion from its own nerves. We have satisfactorily shown, however, that a communication with the nervous centres is absolutely necessary in all cases, and that we can immediately cut off sensation in the portion of a nerve included between two ligatures, and as instantly restore it by removing the upper ligature, and renewing the communication with the brain.

a. External Sensations.

The external sensations are those perceptions which are occasioned by the impressions of bodies external to the part impressed. They are not confined to impressions made by objects external to us. The hand

[1] Med. Literature, p. 93. Lond., 1813.

[2] Physiological Lectures, exhibiting a view of Mr. Hunter's Physiology, &c. Lond., 1817.

[3] The Physiological Anatomy and Physiology of Man, p. 242. Lond., 1845.

[4] An Elementary System of Physiology, 3d edit., p. 148. Lond., 1836.

[5] De Structurâ Nervorum, Hal., 1796.

[6] Traité de la Structure du Cœur, &c., liv. iv. chap. 8. Paris, 1749.

[7] Tabulæ Neurologicæ. Ticin., 1794, § 22.

applied to any part of the body; any two of its parts brought into contact; or the presence of its own secretions or excretions may equally excite them. M. Adelon,[1] has divided them into two orders—*first*, the *senses*, properly so called, by the aid of which the mind acquires its notion of external bodies, and of their different qualities; and *secondly*, those sensations which are still caused by the contact of some body, and yet afford no information to the mind.

It is by the external senses, that we become acquainted with the bodies that surround us. They are the instruments by which the brain receives its knowledge of the universe; but they are only instruments, and cannot be considered as the sole regulators of the intellectual sphere of the individual. This we shall see is dependent upon another and still higher nervous organ,—the brain.

The external senses are generally considered to be five in number; for, although others have been reckoned, they may perhaps be reduced to some modification of these five,—*tact* or *touch*, *taste*, *smell*, *hearing*, and *vision*. All these have some properties in common. They are situate at the surface of the body, so as to be capable of being acted upon with due facility by external bodies. They all consist of two parts;—the one, *physical*, which modifies the action of the body, that causes the impression; the other *nervous* or *vital*, which receives the impression, and conveys it to the brain. In the eye and the ear, we have better exemplifications of this distinction than in the other senses. The physical portion of the eye is a true optical instrument, which modifies the light, before it impinges upon the retina. A similar modification is produced by the physical portion of the ear on the sonorous vibrations before they reach the auditory nerve; whilst, in the other senses, the physical portion forms a part of the common tegument in which the nervous portion is seated, and cannot be easily distinguished. Some of them, again, as the skin, tongue, and nose, are symmetrical, that is, composed of two separate and similar halves, united at a median line. Others, as the eye and ear, are in pairs; and this, partly perhaps, to enable the distances of external objects to be appreciated. We shall find, at least, that there are certain cases, in which both the organs are necessary for accurate appreciation.

Two of the senses—vision and audition—have, respectively, a nerve of special sensibility; and, until of late years, the smell was universally believed to be similarly situate. In the present state of our knowledge, we cannot decide upon the precise nerve of taste, although it will be seen that a plausible opinion may be indulged on the subject. The general sense of touch or feeling is certainly seated in the nerves of general sensibility connected with the posterior roots of the spinal nerves, and the fifth encephalic pair; and according to some,[2] in the glosso-pharyngeal and pneumogastric nerves. The other senses seem intimately connected with one nerve of general sensibility,—the fifth pair. This is especially the case with those senses that possess nerves of special sensibility; for, if the fifth pair be cut, the function is abolished or impaired, although the nerve of special sensibility may remain entire.

[1] Physiologie de l'Homme, tom. i. p. 259, 2de édit. Paris, 1829.
[2] Longet, Traité de Physiologie, ii. 176, note. Paris, 1850.

Being instruments by which the mind becomes acquainted with external bodies, it is manifestly of importance, that the senses should be influenced by volition. Most of them are so. The touch has the pliable upper extremity, admirably adapted for the purpose. The tongue is movable in almost every direction. The eye can be turned by its own immediate muscles towards objects in almost all positions. The ear and the nose possess the least individual motion; but the last four, being seated in the head, are capable of being assisted by the muscles adapted for its movements.

All the senses may be exercised *passively* and *actively*. By directing the attention, we can render the impression more vivid; and hence the difference between simply seeing or passive vision, and looking attentively; between hearing and listening; smelling and snuffing; touching and feeling closely. It is to the active exercise of the senses, that we are indebted for many of the pleasures and comforts of social existence. Yet, to preserve the senses in the vigour and delicacy, which they are capable of acquiring by attention, the impressions must not be too constantly or too strongly made. The occasional use of the sense of smell, under the guidance of volition, may be the test on which the chemist, perfumer, or wine-merchant, may rely in the discrimination of the numerous odorous characteristics of bodies; but, if the olfactory nerves be constantly, or too frequently, stimulated by excitants, of this or any other kind, dependence can no longer be placed upon them as a means of discrimination. The maxim that "habit blunts feeling," is true only in such cases as the last. Education can, indeed, render it extremely acute.[1] Volition, on the other hand, enables us to deaden the force of sensations. By corrugating the eyebrows, and approximating the eyelids, we can diminish the quantity of light when it is too powerful. We can breathe through the mouth, when a disagreeable odour is exhaled around us; or, with the aid of the upper extremity, can completely shut off its passage by the nostrils. Over the hearing we have less command as regards its individual action: the upper extremity is here always called into service, when we desire to diminish the intensity of any sonorous impression.

Lastly. It is a common observation, that the loss of one sense occasions greater vividness in others. This is only true as regards the senses that administer chiefly to the intellect,—those of touch, audition, and vision, for example. Those of smell and taste may be destroyed; and yet the more intellectual senses may be uninfluenced. In the singular condition of artificial somnambulism or hypnotism, the author has seen the various senses rendered astonishingly acute.

The cause of the superiority of the remaining intellectual senses, when one has been lost, is not owing to any superior organization in those senses; but is another example of the influence of education. The remaining senses are exerted attentively to compensate for the privation; and they become surprisingly delicate.

We proceed to the consideration of the separate senses, beginning with that of *tact* or *touch*, because it is most generally distributed, and

[1] Bérard, Rapport du Physique et du Moral, p. 245; Paris, 1823.

may be regarded as that from which the others are derived. They are all, indeed, modifications of the sense of touch. In the taste, the sapid body; in the smell, the odorous particle; in the hearing, the sonorous vibration; and in the sight, the particle of light, must impinge upon or *touch* the nervous part of the organ, before sensation can, in any of the cases, be effected.

A. SENSE OF TACT OR TOUCH—PALPATION.

The sense of tact or touch is the general feeling or sensibility, possessed by the skin especially, which instructs us regarding the temperature and general qualities of bodies. By some, touch is restricted to the sense of resistance alone; and hence they have conceived it necessary to raise into a distinct sense one of the attributes of tact or touch. The sense of heat, for example, has been separated from tact; but although the appreciation of external bodies by tact or touch differs —as will be seen—in some respects from our appreciation of their temperature, its consideration properly belongs to the sense we are considering, in the acceptation here given to it, and adopted by all the French physiologists. According to them, tact is spread generally in the organs, and especially in the cutaneous and mucous surfaces. It exists in all animals; whilst touch is exercised only by parts evidently destined for that purpose, and is not present in every animal. It is nothing more than tact joined to muscular contraction and directed by volition. So that, in the exercise of tact, we may be esteemed *passive;* in that of touch, *active.*

The organs concerned in touch, execute other functions besides; and in this respect touch differs from the other senses. Its chief organ, however, is the skin; and hence it is necessary to inquire into its structure, so far as is requisite for our purpose.

1. ANATOMY OF THE SKIN, HAIR, NAILS, ETC.

The upper classes of animals agree in possessing an outer envelope or skin, through which the insensible perspiration passes; a slight degree of absorption takes place; the parts beneath are protected; and the sense of touch is accomplished. In man, the skin is generally considered to consist of four parts,—the cuticle, rete mucosum, corpus papillare, and corium; but when reduced to its simplest expression, the whole of the integument, with the mucous membrane, which is an extension of it, may be regarded as a continuous membrane, more or less involuted, more or less modified by the elementary tissues which compose it or are in connexion with it, and within which all the rest of the animal is contained. It consists of two elements—a *basement tissue* or *membrane*, composed of simple membrane, uninterrupted, homogeneous, and transparent; covered by an *epithelium* or pavement of nucleated particles.[1]

1. The *epidermis* or cuticle is the outermost layer. It is a dry, membranous structure, devoid of vessels and nerves; yet it is described by some modern investigators as a tissue of a somewhat complex organiza-

[1] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 404, London, 1845.

tion, connected with the functions of exhalation and absorption; but its vitality is regarded to be on a par with that of vegetables. The absence of nerves proper to it renders it insensible; it is coloured; and exhales and absorbs in the manner of vegetables. It is, so far as we know, entirely insensible; resists putrefaction for a long time, and may be easily obtained in a separate state from the other layers by maceration in water. It is the thin pellicle raised by a blister.

The cuticle is probably a secretion or exudation from the true skin, which concretes on the surface; becomes dried, and affords an efficient protection to the corpus papillare beneath. It is composed, according to some, of concrete albumen; according to others, of mucus; and is pierced by oblique pores for the passage of hairs, and for the orifices of exhalant and absorbent vessels. MM. Breschet and Roussel de Vauzème[1] affirm, that there is a special "*blennogenous* or *mucific apparatus*" for the secretion of this mucous matter, composed of a glandular parenchyma or organ of secretion situate in the substance of the derma, and of excretory ducts, which issue from the organ, and deposit the mucous matter between the papillæ; but such an apparatus is not admitted.

It is probable, that the cuticle is placed at the surface of the body, not simply to protect the corpus papillare; but to prevent the constant imbibition and transudation that might take place did no such envelope exist. It exfoliates, in the form of scales, from the head; and in large pieces, from every part of the body, after certain cutaneous diseases.

M. Flourens,[2] who has closely and accurately investigated the anatomy of the cutaneous envelope, considers that the skin of the coloured races has an apparatus, which is wanting in the white variety of the species. This apparatus he names pigmental,—*appareil pigmental*. It is composed of a layer (*lame*) or membrane which bears the pigment, and of the pigment itself. Above it are two cuticles. In the white variety the pigmental apparatus is wanting, and consequently the skin is more simple than that of the coloured races. The skin of the white variety approaches that of the coloured in some remarkable points. *First.*—The superficial layer or *lame* of the derma is everywhere of a peculiar appearance, which is different from that of the rest of the derma. *Secondly.*—Around the nipple of the white woman, the superficial layer of the derma presents the same granular appearance as the *pigmental membrane* of the coloured races. And *thirdly.*—The *pigmental layer* around the nipple of the white woman is placed, as in the coloured races, under the two cuticles.

Modern histologists consider the epidermis to be composed of a series of flattened, scale-like cells, *epidermic cells*, which, when first formed, are of a spheroidal shape; but gradually dry up. These form various layers. According to M. Raspail,[3] it consists of a collection of vesicles deprived of their contents, closely applied together, dried and thrown off in the form of branny scales. He regards it as the outer layer of the corium.

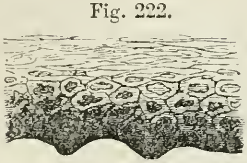
The epidermoid tissues have the simplest structure of any solids.

Analysis has shown, that the chemical constitution of the mem-

[1] Nouvelles Recherches sur la Structure de la Peau, par M. Breschet, Paris, 1835.
[2] Anatomie Générale de la Peau et des Membranes Muqueuses, p. 34, Paris, 1843.
[3] Chimie Organique, p. 245, Paris, 1833.

branous epidermis of the sole of the foot is the same as that of the compact horny matter of which nails, hair, and wool are composed.

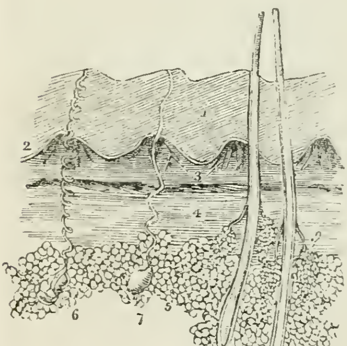
Fig. 222.



Vertical Section of the Cuticle, from the Scrotum of a Negro.

a. Deep cells, loaded with pigment. *b.* Cells at a higher level, paler and more flattened. *c.* Cells at the surface, scaly and colourless as in the white races.—Magnified 300 diameters.

Fig. 223.



Section of the Skin.

1. Cuticle, showing the oblique laminæ of which it is composed, and the imbricated disposition of the ridges upon its surface. 2. Rete mucosum. 3. Two of the quadrilateral papillary masses seen in the palm of the hand or sole of the foot; they are composed of minute conical papillæ. 4. Deeper layer of the cutis, the corium. 5. Adipose vesicles; showing their appearance beneath the microscope. 6. Perspiratory gland with its spiral duct, as seen in the palm of the hand or sole of the foot. 7. Another perspiratory gland with a straighter duct, such as seen in the scalp. 8. Two hairs from the scalp, enclosed in their follicles; their relative depth in the skin preserved. 9. A pair of sebaceous glands opening by short ducts into the follicle of the hair.

2. The *corpus* or *rete mucosum*, *rete Malpighii*, *mucous web*, is generally regarded as constituting the next layer. It was considered by Malpighi to be mucus, secreted by the papillæ, and spread on the surface of the corpus papillare, to preserve it in the state of suppleness necessary for the performance of its functions. In this rete mucosum, the colouring matter of the dark races seems to exist. It is black in the African, or rather in the Ethiopian; and copper-coloured in the mulatto.[1] Gaultier[2] considers it to be composed of four layers; but this notion is not admitted by anatomists, and scarcely concerns the present inquiry. M. Breschet affirmed, that there is a special "*chromatogenous* or *colorific apparatus*," for producing the colouring matter, composed of a glandular or secreting parenchyma, situate a little below the papillæ, and presenting special excretory ducts, which pour out the colouring matter on the surface of the derma. Modern observers deny, that there is any such distinct layer. Some regard it as the deepest or most recently formed part of the cuticle. M. Flourens[3] considers, that the term corpus mucosum ought to be replaced by that of pigmental apparatus,—*appareil pigmental;* and that the term *rete* or *corpus reticulare* in the signification of a special network situate between the derma and the two cuticles, ought to be banished from anatomy. The nature of the pigment will be referred to hereafter, under Secretion.

The rete mucosum is considered to be the last formed portion of the cuticle.

3. The *corpus papillare*, or what M. Breschet calls the "*neurothelic* or *mammillary nervous apparatus*," is seated next below the rete mucosum. It consists of a collection of small papillæ, formed by the extremities

[1] Sir E. Home, Lect. on Comp. Anat., v. 278.
[2] Recherches Anatomiques sur le Système Cutané de l'Homme, Paris, 1811.
[3] Op. cit., p. 38.

of nerves and vessels, which, after having passed through the corium beneath, are grouped in small pencils or villi on a spongy, erectile tissue. These pencils are disposed in pairs, and, when not in action, are relaxed, but become erect when employed in the sense of touch. They are very readily seen, when the cutis vera is exposed by the action of a blister; and are always evident at the palmar surface of the hand, and especially at the tips of the fingers, where they have a concentric arrangement. These villi are sometimes called *papillæ.* They are, in reality, prolongations of the skin; and consequently—as M. Flourens[1] has remarked—"the pretended *corpus papillare*, taken as a body, apart and distinct from the derma, is but an idle name."

Fig. 224.

Papillæ of the Palm, the Cuticle being detached.—Magnified 35 diameters.

In parts that are endowed with much tactile sensibility, the cutaneous nerve fibres—as of the papillæ of the palm of the hand—terminate in the corpuscles of touch already mentioned.[2]

4. The *corium*, *cutis vera*, *derma* or *true skin*, is the innermost layer of the skin. It consists of a collection of dense fibres, intersecting each other in various directions; and leaving between them holes for the passage of vessels and nerves. It forms a firm stratum, giving the whole skin the necessary solidity for accomplishing its various ends; and consists chiefly of gelatin;—hence it is used in the manufacture of glue. Gelatin, when united with tannic acid, forms a substance which is insoluble in water; and it is to this combination that leather owes the properties it possesses. The hide is first macerated in lime-water to remove the cuticle and hairs, and leave the corium or gelatin. This is then placed in an infusion of oak bark, which contains tannic acid. The tannic acid and the skin unite; and leather is the product.

These four strata constitute the *skin*, as it is commonly called; yet all are comprised in the thickness of two or three lines. The cutis vera is united to the structures below by areolar tissue; and this, with the layers external to it, forms the *common integument.* In certain parts of the body, and in animals more particularly, the cutis vera is adherent to muscular fibres, inserted more or less obliquely. These form the *muscular web*, *mantle*, or *panniculus carnosus.* The layer is well seen in the hedgehog and porcupine, in which it rolls up the body, and erects the spines; and in birds raises the feathers. In man, it can hardly be said to exist. Some muscles, however, execute a similar function. By the occipito-frontalis, many persons can move the hairy scalp; and by the dartos the skin of the scrotum can be corrugated. These two parts, therefore, act as *panniculi carnosi.*

The skin itself also possesses smooth muscular fibres, which give occasion to its contractility, as seen in the corrugation of the scrotum, the erection of the nipple, and the phenomena of the cutis anserina.

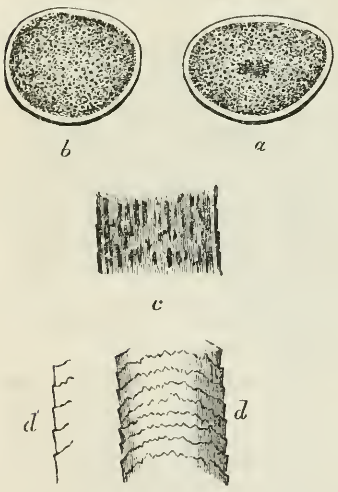
[1] Op. cit., p. 38.

[2] Page 640. See, on the nature of these bodies, Wagner, in Müller's Archiv., 1852, Heft 4; Kölliker, Mikroskopische Anatomie, Bd. ii. S. 24; and Amer. edit. of Sydenham Society's edition of his Human Histology, by Dr. Da Costa, p. 129, Philad., 1854; and Mr. Huxley, Quarterly Journal of Microscopical Science, ii. 1.

These have been found by Froriep, Brown-Séquard, and Kölliker to contract on the application of electricity.[1] The cutis anserina consists in local contractions of the portions of the skin around the hair follicles, by which their apertures are protruded conically, by muscular fibres discovered by Kölliker, which pass obliquely from the superficial part of the cutis down to the follicles, and, when they contract, protrude the follicles, and retract those portions of the skin whence they arise.

In the skin are situate numerous *sebaceous follicles* or *crypts*, which separate an oily fluid from the blood, and pour it over the surface to lubricate and defend it from the action of moisture. They are most abundant, where there are folds of the skin, or hairs, or where the surface is exposed to friction. We can generally see them on the pavilion of the ear, and their situation is often indicated by small dark spots on the surface, which, when pressed between the fingers, may be forced out along with the sebaceous secretion, in the form of small worms. By the vulgar, indeed, they are considered to be worms. The follicular secretions have engaged attention elsewhere.

Fig. 225.



Sections of Hair.

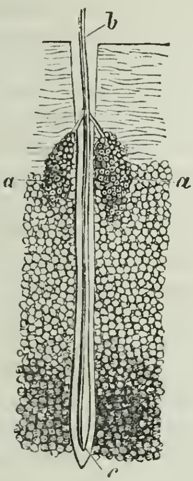
a. Transverse section of a hair of the head, showing the exterior cortex, the medulla or pith with its scattered pigment, and a central space filled with pigment. *b.* A similar section of a hair, at a point where no aggregation of pigment in the axis exists. *c.* Longitudinal section, without a central cavity, showing the imbrication of the cortex, and the arrangement of the pigment in the fibrous part. *d.* Surface showing the sinuous transverse lines formed by the edges of the cortical scales. *d′.* A portion of the margin, showing their imbrication.—Magnified 150 diameters.

The consideration of the *hair* belongs naturally to that of the skin. The roots are in the form of bulbs; taking their origin in small follicles or open sacs, *hair follicles*, formed by the inversion of the cutis, and lined by a reflexion of the epidermis. Around each bulb there are two capsules, the innermost of which is vascular and a continuation of the corium. The hair itself consists of a horny, external covering, and a central part, called *medulla* or *pith*. When we take hold of a hair by the base, with the thumb and forefinger, and draw it through them from the root towards the point, it feels smooth to the touch; but if we draw it through from the point to the root, we feel the surface rough; and it offers considerable resistance. It is, therefore, concluded, that the hair is bristled, imbricated, or consists of eminences pointing towards its outer extremity, and it is upon this structure, that the operation of felting is dependent—the hairs being mechanically entangled and retained in that state by the

[1] Kölliker, Experiments, &c., on the Body of an Executed Criminal, in Goodsir's Annals of Anatomy and Pathology, for May, 1852, No. 2, p. 109; and Mikroskopische Anatomie; or Amer. edit., by Dr. Da Costa, of Sydenham Society's edition of his Manual of Histology, by Messrs. Busk and Huxley, p. 138, Philad., 1854.

inequalities of their surface. Certain observers have, however, failed in detecting this striated appearance by the aid of the microscope; and Dr. Bostock[1] affirms, that he had an opportunity of viewing the human

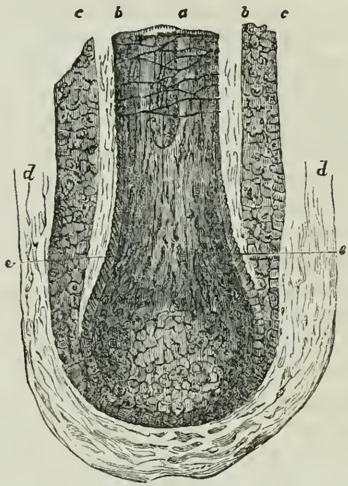
Fig. 226.



Thin Layer from the Scalp.

a, a. Sebaceous glands. *b.* Hair, with its follicle, *c.*

Fig. 227.



Magnified view of the Root of the Hair.

a. Stem or shaft of hair cut across. *b.* Inner, and *c,* outer layer of the epidermic lining of the hair follicle, called also the root-sheath. *d.* Dermic or external coat of the hair follicle, shown in part. *e.* Imbricated scales about to form a cortical layer on the surface of the hair.

hair, and the hair of various kinds of animals, with the excellent microscope of Mr. Bauer, but without being able to observe it. Bichat,[2] however, and more recently, Dr. Goring,[3] and most histologists, have assigned this as their structure; and the author has had repeated opportunities for confirming it.

Modern observers believe, that, as in other structures, growth takes place from cells, which are a modification of those of the epidermis. The primary cells become elongated, and generate within themselves fasciculi of fibres or secondary cells, which interlace to form the hair cylinder. The walls of these fibre-cells are at first soft and permeable; and the lower part of the hair, which is composed of them, seems to admit the passage of fluid without much difficulty. At a short distance from the base, the horny character of the hair, caused by the deposit of horny matter in the interior of the fibres, becomes apparent. "There is then, at the base, a continual formation of soft fibrous tissue, by which the length of the cylinder is increased; whilst at a short distance above it, there is a continual consolidation of this (as it progressively arrives at that point) by the deposit of a peculiar secretion in its substance."[4]

The shape of the hair is different in different races. It is described

[1] Physiology, p. 52, 3d edit., Lond., 1836. [2] Anat. Général., tom. iv. § 2.
[3] Journal of Science, New Series, vol. i. 433.
[4] Carpenter, Human Physiology, § 637. Lond., 1842.

as cylindrical in the American Indian; oval in the white man, and eccentrically elliptical or flat in the negro.[1] Its colour also differs in different races and individuals. By some, this is considered to depend upon the fluids contained in the pith. M. Vauquelin[2] analyzed the hair attentively, and found it to consist chiefly of an animal matter, united to a portion of oil, which appeared to contribute to its flexibility and cohesion. Besides this, there is another substance, of an oily nature, from which he considers the colour of the hair is derived. The animal matter, according to that chemist, is a species of mucus; but other chemists believe it to be chiefly albumen. Vauquelin found, that the colouring matter is destroyed by acids; and he suggests, that when it has suddenly changed colour and become gray, in consequence of any mental agitation, this may be owing to the production of an acid in the system, which acts upon the colouring matter. The explanation is hypothetical, and is considered, and characterized as such by Dr. Bostock; but it must be admitted, that the same objection applies to the view he has substituted for it. He conceives it "more probable that the effect depends upon a sudden stagnation in the vessels, which secrete the colouring matter; while the absorbents continue to act, and remove that which already exists." There is, however, no more real evidence of "stagnation of vessels" than there is of the formation of an acid. Our knowledge is limited to the fact, that a sudden and decided change in the whole pileous system may occur after great or prolonged mental agitation.

"My hair is gray, but not with years,
Nor grew it white in a single night,
As men's have grown from sudden fears."
Byron's "*Prisoner of Chillon.*"

"Danger, long travail, want and wo,
Soon change the form that best we know:
For deadly fear can time outgo,
And blanch at once the hair.
Hard toil can roughen form and face,
And want can quench the eye's bright grace,
Nor does old age a wrinkle trace
More deeply than despair."
Scott's "*Marmion.*"

It is stated,[3] that such a change occurred in a single night to the queen of Louis the 16th—the unfortunate Marie Antoinette—when the royal party was arrested at Varennes, in 1791.[4]

But a similar, though more gradual change is produced by age. We find some persons entirely gray at a very early period of life; and, in old age, the change happens universally. It is not then difficult to suppose, that some alteration in the nutrition of the hair may

[1] P. A. Browne, The Classification of Mankind by the Hair and Wool of their Heads, p. 4, Philad., 1850, and Trichologia Mammalium, p. 51. Philad., 1853.

[2] Annales de Chimie, tom. lviii. p. 41, Paris, 1806.

[3] "La reine ne dormit pas. Toutes ses passions, de femme, de mère, de reine, la colère, la terreur, la desespoir, se livrèrent un tel assaut dans son âme, que ses cheveux, blonds la vieille, furent blancs le lendemain."—De Lamartine, *Histoire des Girondins*, i. 116. Paris, 1847.

[4] Several cases are recorded in Mr. Erasmus Wilson, Healthy Skin, Amer. edit., p. 114, Philad., 1854.

supervene, resembling that which occurs in the progress of life. Dr. Bostock doubts the fact of such sudden conversions; but the instances are too numerous for us to consider them entirely fabulous. Still, it is difficult to comprehend how parts, which, like the extremities of the hair, are foreign to nutrition, can change so rapidly. M. Lepelletier[1] ascribes it to two very different causes. *First*, to defective secretion of the colouring fluid, without any privation of nutrition. In this case, the hairs may live and retain their hold, as we observe in young individuals:—and *secondly*, to the canals, which convey the fluid into the hair being obliterated, as in old age. The same cause, acting on the nutritious vessels of the bulb, produces successively, privation of colour, death, and loss of those epidermoid productions. A case related by M. Paget[2]—and which he esteems authentic—is, as he properly remarks, in near relation to those in which the hair grows quickly gray in mental anguish. A lady, who is subject to attacks of what are called nervous headaches, always finds in the morning, after one of them, that some patches of her hair are white, as if powdered with starch. "The change is effected in a night, and in a few days after, the hairs gradually regain their dark brownish colour."

According to other physiologists, the seat of colour is in the horny covering of the hair; and in the largest hairs or spines of the porcupine this seems to be the case, the pith being white, and the horny covering coloured. There is often an intimate relationship observed between the colour of the hair and that of the skin. A fair complexion is accompanied with light hair; a swarthy with dark;—and we see the connexion still more signally displayed in those animals that are spotted,—the colour of the hair being variegated like that of the skin.

Hairs differ materially according to the part of the body on which they grow. In some parts they are short, as in the armpits; whilst on the head it is not easy to say what would be the precise limit to the growth, were they left entirely to nature. In the Malay, it is by no means uncommon to see them touch the ground.

The hair has various names assigned to it, according to the part on which it appears,—*beard*, *whiskers*, *mustachios*, *eyebrows*, *eyelashes*, &c. In many animals it is long and straight; in others crisped, when it is called *wool*. If stiff, it is termed a *bristle;* if inflexible, a *spine*. It is entirely insensible, and, excepting in the bulbous portion, is not liable to disease. Dr. Bostock affirms, that under certain circumstances hairs are subject to a species of inflammation, when vessels may be detected, at least in some of them, and they become acutely sensitive. Their sensibility under any known circumstance may be doubted. They appear to be anorganic, except at the root; and, like the cuticle, resist putrefaction for a length of time. The parts that do not receive vessels are nourished by transudation from those that do. Bichat and Gaultier were of the opinion of Dr. Bostock,—misled, apparently, by erroneous reports concerning plica polonica; but Baron Larrey[3] has

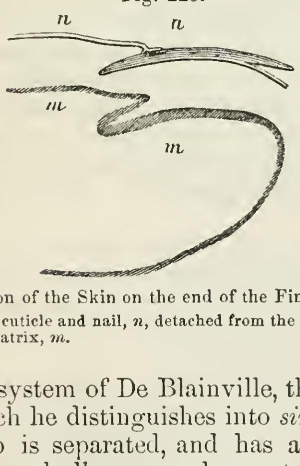
[1] Traité de Physiologie Médicale et Philosophique, tom. iii. p. 42, Paris, 1832.
[2] Lectures on Surgical Pathology, Amer. edit., p. 44, Philad., 1854.
[3] Mémoires de Chirurgie Militaire, t. iii. 108, Paris, 1812.

satisfactorily shown that plica is confined to the bulbs: the hairs themselves continue devoid of sensibility.

It is difficult to assign a plausible use for the hair. That of the head has already engaged attention; but the hair, which appears on certain parts at the age of puberty and not till then, and that on the chin and upper lip of the male sex only, set our ingenuity at defiance. In this respect, the hair is not unique. Many physiologists regard certain parts, which exist in one animal, apparently without function, but which answer useful purposes in another, to be *vestiges* indicating the harmony that reigns through nature's works. The generally useless nipple and mamma of one sex might be looked upon in this light; but the tufts of hair on various parts cannot, in any way, be assimilated to the hairy coating that envelopes the bodies of animals; and is, in them, manifestly intended as a protection against cold.

There is another class of bodies connected with the skin, and analogous in nature to the last described,—the *nails*. These serve a useful purpose in touch, and consequently require notice here. In

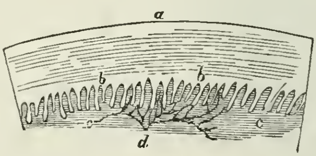
Fig. 228.



Section of the Skin on the end of the Finger.

The cuticle and nail, *n*, detached from the cutis and matrix, *m*.

Fig. 229.



A transverse Section of a Finger-Nail, showing the manner in which it is connected with the sensitive skin by its under surface.

a. The nail laminated in texture. *b b*. The vertical plates of its under surface. *c c*. The sensitive skin, which sends up folds between the plates of the nail. *d*. A small bloodvessel supplying the sensitive skin and its folds.

the system of De Blainville, they constitute a subdivision of the hairs, which he distinguishes into *simple* and *compound*,—*simple*, when each bulb is separated, and has a distinct hair;—*compound*, when several pileous bulbs are agglomerated, so that the different hairs, as they are formed, are cemented together to constitute a solid body of greater or less size,—*nail*, *scale*, *horn*, &c. In man, the nail alone exists; the chief and obvious use of which is to support the pulp of the finger, whilst it is exercising touch. Animals are provided with horns, beaks, hoofs, nails, spurs, scales, &c. All these, like the hair, grow from roots; and are considered to be analogous in their physical and vital properties. Meckel, De Blainville, Bonn, Walther, Lavagna, and others, are of opinion, that the teeth are of the same class; and that they belong, originally, to the skin of the mouth.

The nails, near their origin, are seen, under the microscope, to consist of primary cells, almost identical with those of the epidermis; these gradually dry into scales; and the growth of the nail appears to be effected by the constant generation of cells at its root and under surface; and as successive layers are pushed forward, each cell becomes larger, flatter, and drier, and more firmly fixed than those around it.[1] The chemical composition of the epidermis and the nails is similar to that of the hair: yet according to Mulder,[2] there are material differences in their properties;—the latter, being almost insoluble in strong acetic acid, in which the other two are readily soluble: hence—he infers—the composition of hair and of horn and whalebone must differ materially; and, that, accordingly, Scherer's conclusion, that they are all identical is incorrect. The following are the results of the analysis of each of these bodies.

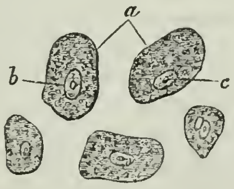
	Epidermis.	Horn.	Whalebone.	Hair.
C.	50·28	51·03	51·86	50·65
H.	6·76	6·80	6·87	6·36
N.	17·21	16·24	15·70	17·14
O.	25·01	22·51	21·97	20·85
S.	0·74	3·42	3·60	5·00

For physiological purposes, the above description is sufficient.

Mucous Membranes.—A few words will be necessary regarding the mucous membranes, which resemble the skin so much in their properties, as to be, with propriety, termed *dermoid.* If we trace the skin into the various outlets, we find, that a continuous, soft, velvety membrane exists through their whole extent; and, if the channel has two outlets, as in the alimentary canal, this membrane, at each outlet, commingles with the skin; and appears to differ but slightly from it. So much, indeed, do they seem to form part of the same organ, that physiologists have described the absorption, that takes place from the intestinal mucous membrane, as *external.* They cannot, however, in the higher order of animals, be considered completely identical; nor is the same membrane alike in its whole extent. They have all been referred to two great surfaces;—the *gastro-pulmonary*—comprising the membranes of the outer surface of the eye, ductus ad nasum, nose, mouth, and respiratory and digestive passages; and the *genito-urinary*—which line the whole of the genital and urinary apparatuses. In addition to these, a membrane of similar character lines the meatus auditorius externus, and the excretory ducts of the mammæ.

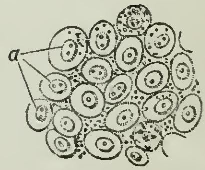
Fig. 230.

A



Separated Epithelium Cells from mucous membrane of mouth.
b. With nuclei. *c.* And nucleoli.

B



Pavement-Epithelium of the Mucous Membrane of the smaller bronchial tubes.
a. Nuclei with double nucleoli.

The analogy between the skin and mucous membranes is farther shown by the fact, that if we invert the polypus, the mucous membrane

[1] Henle, edit. cit., i. 289, Paris, 1843.

[2] The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 527. Edinb. and London, 1849.

gradually assumes the characters of skin; and the same circumstance is observed in habitual descents of the rectum and uterus.

In the mucous membranes—especially at their extremities, which appear to be alone concerned in the sense of touch—the same superposition of strata is generally considered to exist as in the skin—viz., epidermis or epithelium, rete mucosum, corpus papillare, and cutis vera. They have, likewise, similar follicles, called *mucous;* but nothing analogous to the hairs; unless we regard the teeth to be so, in correspondence with the views of Meckel, De Blainville, and others.

The attention of anatomists has been closely directed to the ultimate structure of the mucous system. In the mucous tissues two structures have been separately described,—especially by Mr. Bowman,[1] who has thrown much light on the subject. These are the *basement membrane*—as he terms it—and *the epithelium.* The former is a simple, homogeneous expansion, transparent, colourless, and of extreme tenuity, situate on its parenchymal surface, and giving it shape and strength. This serves as a foundation on which the epithelium rests. It may frequently be demonstrated with very little trouble in the tubuli of the glands, especially of the kidney, which are but very slightly adherent, by their external surface, to the surrounding tissue.

M. Flourens[2] considers that every mucous membrane is composed of three laminæ or layers,—the derma, epidermis, and corpus mucosum situate between the derma and epidermis. The corpus mucosum of mucous membranes is continuous at all the outlets of the body, and is identical with the second epidermis; differing, therefore, from the corpus mucosum of the skin, a term which—as elsewhere remarked—he thinks ought to be abolished.

Histological examination exhibits the epithelium to consist of cells, which are termed *epithelial*, and have various shapes. The two chief are *tesselated* or *pavement epithelium*, and *cylinder* or *conical epithelium.* Epithelium is not, however, confined to mucous membranes, but, of late years, has been found to exist elsewhere; it is always in contact with fluids, and of a soft, pliant character. *Tesselated epithelium* covers the serous and synovial membranes, the lining membrane of the blood-vessels, and the mucous membranes, except where cylinder epithelium exists. It is spread over the mouth, pharynx and œsophagus, conjunctiva, vagina, and entrance of the female urethra. The cells composing it are usually polygonal; and are well seen in the marginal figure. *Cylinder epithelium* is found in the intestinal canal, beyond the cardiac orifice, in the larger ducts of the salivary glands, in the ductus communis choledochus, prostate, Cowper's glands, vesiculæ seminales, vas deferens, tubuli uriniferi, and urethra of the male; and lines the urinary passages of the female from the orifice of the urethra to the beginning of the tubuli

Fig. 231.

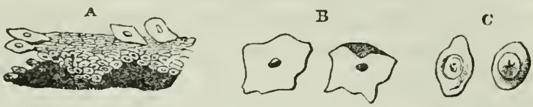
Tesselated Epithelium.

Extremity of one of the tubuli uriniferi, from the kidney of an adult; showing its tesselated epithelium.—Magnified 250 diameters.

[1] Cyclopædia of Anat. and Physiology, pt. xxiii. p. 486, April, 1842.
[2] Op. cit., p. 80.

uriniferi of the kidney. In all these situations, it is continuous with tesselated epithelium, which lines the more delicate ducts of the various

Fig. 232.

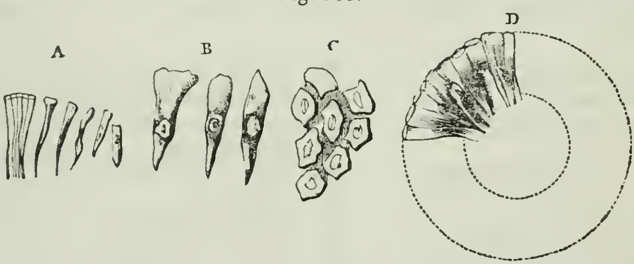


Scales of Tesselated Epithelium.

A. Section of epithelium of conjunctiva with some scales loosened. B. Scales from surface of cheek. C. The more deeply seated scales from the human conjunctiva.

glands. The cells have the form of long cylinders or truncated cones, arranged side by side, the apices attached to the mucous membrane or to flat epithelial cells lying upon it; the base being free. Each cell, nearly midway between the base and apex, encloses a flat nucleus with

Fig. 233.



Cylinders of Intestinal Epithelium. (After Henle.)

A. From the cardiac region of the human stomach. B. From jejunum. C. Cylinders seen when looking on their free extremities. D. Ditto, as seen in a transverse section of a villus.

nucleoli. Epithelium is sometimes furnished with *cilia*, or is said to be *ciliated*. The nature and uses of these cilia, as well as the different varieties of mucous membrane, will be described hereafter.

2. PHYSIOLOGY OF TACT AND TOUCH.

In describing the physiology of the sense of touch, it will be convenient to revert to the distinction already made between the sense when passively and actively exerted; or between *tact*, and *touch*. The mode, however, in which the impression is made is in each case alike, and equally simple. It is merely necessary, that the substance, which causes it, should be brought in contact with what may be termed the physical part of the organ—the cuticle; the nervous part is seated in the corpus papillare, for if the nerves proceeding to this layer of the skin be cut, the sense is destroyed. In the exercise of touch, each of the layers seems to have its appropriate office: the corium, the innermost layer, the base on which the others rest, offers the necessary resistance, when bodies are applied to the surface; the rete mucosum is unconcerned in the function: the erectile tissue, on which the papillæ are grouped, probably aids them in their appreciation of bodies; and the epidermis modifies the tactile impression which might become too intense, or be painful, did this anorganic envelope not exist. The degree of perfection of the sense is greatly influenced by the state of the cuticle. Where thin—as upon the lips, glans penis, clitoris, &c.—the sense is very acute; where thick and hard, it is obtuse; and where removed—as by blistering—the contact of bodies gives pain, but does not occasion the appropriate impression of touch.

Professors Weber[1] and Valentin[2] have shown that the tactile power of the skin is not proportionate to its sensibility. The mammæ, for example, are easily tickled, and susceptible of great pain when irritated; yet they are moderately endowed with the sense of touch. The different parts of the skin, too, vary in their tactile power. The left hand, in most persons, is more sensible to temperature than the right, probably owing to the epidermis being thinner from less use.

Weber made various experiments for the purpose of determining the relative sensibility of different portions of the skin, by touching the surface with the legs of a pair of compasses, the points of which were inserted into pieces of cork. The person's eyes being closed at the time, the legs were brought together so as to be separated by different distances. The following are some of the results of his experiments.

	Lines.		Lines.
Point of middle finger	$\frac{1}{3}$	Mucous membrane of gums	9
Point of tongue	$\frac{1}{2}$	Lower part of forehead	10
Palmar surface of third finger	1	Lower part of occiput	12
Red surface of lips	2	Back of hand	14
Palmar surface of middle finger	2	Neck, under lower jaw	15
Dorsal surface of third finger	3	Vertex	15
Tip of the nose	3	Skin over patella	16
Dorsum and edge of tongue	4	Skin over sacrum	18
Part of lips covered by skin	4	——— acromion	18
Palm of hand	5	Dorsum of foot	18
Skin of cheek	5	Skin over sternum	20
Extremity of great toe	5	Skin beneath occiput	24
Hard palate	6	Skin over spine, in back	30
Dorsal surface of fore finger	7	Middle of the arm	30
Dorsum of hand	8	——— thigh	30[3]

Weber found, that the distance between the legs of the compasses seemed to be greater, although it was really less, when they were placed upon more sensitive parts.

It has been supposed, that some of the recorded instances of great resistance to heat have been caused by unusual thickness, and compactness of cuticle, together with a certain degree of insensibility of the skin. The latter may be an important element in the explanation; but some of the feats, executed by persons of the character alluded to, could hardly have been influenced by the former, as the resistance seemed almost equally great in the delicately organized mucous membranes. A Madame Girandelli,—who was exhibited in Great Britain many years ago,—was in the habit of drawing a box with a dozen

[1] Art. Tastsinn und das Gemeingefühl, in Wagner's Handwörterbuch der Physiologie, 22ste Lieferung, S. 539. Braunschweig, 1849. His earlier experiments are detailed and confirmed by Dr. Allen Thomson, in Edinb. Med. and Surg. Journal, for July, 1833.

[2] Lehrbuch der Physiologie des Menschen, ii. 565. Braunschweig, 1844; and Grundriss der Physiologie, S. 331. Braunschweig, 1846.

[3] A full table of the results of the observations of Professors Weber and Valentin is given by Dr. Carpenter, in Art. Touch, Cyclop. of Anat. and Physiol., iv. 1169, London, 1852.

lighted candles along her arm, putting her naked foot upon melted lead, and of dropping melted sealing-wax upon her tongue, and impressing it with a seal, without appearing to experience uneasiness; and several years ago (1832), a man of the name of Chabert excited in this country the surprise which followed his exhibitions in London a year or two previously, and gave him the appellation of the "Fire King." In addition to the experiments performed by Madame Girandelli, Chabert swallowed forty grains of phosphorus; washed his fingers in melted lead; and drank boiling Florence oil with perfect impunity. For the phosphorus he professed to take an antidote, and doubtless did so. It is probable, also, that agents were used by him to deaden the painful impressions ordinarily produced by hot bodies applied to the surface. A solution of borax or alum spread upon the skin is said to exert a powerful effect of the kind; but, in addition to the use of such agents, there must be a degree of insensibility of the corpus papillare; otherwise it is difficult to understand why those hot substances did not painfully inflame the surface. We see, daily, striking differences in individuals in the degree of sensibility of the mucous membrane of the mouth and gullet, and are frequently surprised at the facility with which certain persons swallow fluids of a temperature that would excite the most painful sensations in others. In this, habit has unquestionably much to do.

The surprising feats of dipping the hand into melted lead, laying hold of a red-hot iron, &c., were explained by M. Boutigny at the meeting of the British Association at Ipswich in 1851 as follows. In all such cases, a thin film of aqueous fluid in the spherical state intervenes between the skin and the heated surface; and a hand, which is naturally damp, or which has been slightly moistened, may, it is affirmed, be safely passed into the stream of melted iron as it flows from the surface, as was shown by M. Boutigny at the meeting.[1]

In the mucous membranes, tact is effected in the same way as in the skin. The layers, of which it is constituted, participate in like manner; but the sense is more exercised at the extremities of the membrane than internally. The food, received into the mouth, is felt there; but after it has passed into the gullet it excites hardly any tactile impression; and it is not until it has reached the lower part of the membrane, in the shape of excrement, that its presence is again indicated by this sense.

Pathologically, we have some striking instances of this difference in different parts of the mucous membrane. If an irritation exists within the intestinal canal, the only indication we may have of it is itching of the nose, or at one extremity of the membrane. In like manner, a calculus in the bladder is indicated by itching of the glans penis; and a similar exemplification is offered during the passage of a gall-stone through the ductus communis choledochus. On its first entrance, the pain experienced is of the most violent character; this, after a time subsides,—as soon, indeed, as the calculus has got fairly into the canal.

[1] Report on the 21st Meeting of the British Association for the Advancement of Science, Lond., 1852; and Carpenter, Principles of Human Physiology, Amer. edit., p. 411 (note), Philad., 1855.

One of the great purposes of the sense of tact is to enable us to judge of the temperature of bodies. This office it executes alone. No other sense participates in it. It requires no previous exercise; is felt equally by the infant and the adult, and requires only the proper development of its organs. The relative temperature of bodies is accurately designated by the instrument called the *thermometer;* but very inaccurately by our own sensations; and the reason of this inaccuracy is sufficiently intelligible. In both cases, the effect is produced by the disengagement of a subtile fluid, called *caloric* or the matter of heat, which pervades all bodies, and is contained in them to a greater or less extent. This caloric is constantly passing and repassing between bodies, either by radiation or by conduction, until there is an equilibrium of caloric and all have the same temperature as indicated by the thermometer. Hence, objects in the same apartment will exhibit, *cœteris paribus*, a like temperature by this test. From this law, however, the animal body must be excepted. The power which it possesses of generating its own heat, and of counteracting the external influences of temperature, preserves it constantly at the same point.

Although, however, all objects may exhibit the same temperature, in the same apartment, when the thermometer is applied to them; the sensations communicated by them may be very different. Hence the difficulty, which the uninstructed have in believing, that they are actually of identical temperature;—that a hearth-stone, for instance, is of the same degree of heat as the carpet in the same chamber. The cause of the different sensations experienced in the two cases is, that the hearthstone is a much better *conductor* of the matter of heat than the carpet. The consequence is, that caloric is more rapidly abstracted by it from the part of the body which comes in contact with it, and the stone appears to be the colder of the two. For the same reason, when these two substances are raised in temperature above that of the human body, the hearth-stone will appear the hotter of the two; because, it conducts caloric and communicates it more rapidly to the body than the carpet.

When the temperature of the surrounding air is higher than 98°, we receive caloric from the atmosphere, and experience the sensation of heat. The human body is capable of being penetrated by the caloric of substances exterior to it, precisely like those substances themselves; but, within certain limits, it possesses the faculty of consuming the heat, and retaining the same temperature. When the temperature of the atmosphere is only as high as our own—an elevation which it not unfrequently attains in many parts of the United States—we still experience the sensation of unusual warmth; yet no caloric is communicated to us. The cause of this feeling is, that we are accustomed to live in a medium of a less elevated temperature, and consequently to give off caloric habitually to the atmosphere.

Lastly, in an atmosphere of a temperature much lower than that of the body, heat is incessantly abstracted from us; and, if rapidly, we have the sensation of cold. From registers, kept by the illustrious founder of the University of Virginia, Mr. Jefferson, at his residence at Monticello,[1] lat. 37° 58′, long. 78° 40′, it appears that the mean

[1] Virginia Literary Museum, p. 36, Charlottesville, 1830.

temperature of that part of Virginia, is about 55½° or 56°; and that the thermometer varies from 5½° in the coldest month, to 94° in the warmest. Now, the temperature of the human body being 98°, it follows, that heat must be incessantly parting from us, and that we ought, therefore, to experience constantly a sensation of cold; and this we should unquestionably do, were we not protected by clothing, and aided by artificial temperature during the colder seasons. Yet, accustomed as the body is to give off caloric, there is a temperature, in which, clothed as we are, we do not feel cold, although we may be disengaging heat to some extent. This temperature may perhaps be fixed somewhere between 70° and 80° in the climate of the middle portions of the United States. So much, however, are our sensations in this respect dependent upon the temperature which has previously existed, that the *comfortable point* varies at different seasons. If the thermometer, for instance, has ranged as high as 98°, and has maintained this elevation for a few days, a depression of 15° or 20° will be accompanied by feelings of discomfort; whilst a sudden elevation from 30° to 75° may occasion an oppressive feeling of heat. In northern Siberia, M. von Wrangel[1] found, that only a few degrees of frost was currently denominated "warm weather;" and that after having been accustomed to the winter temperature of that climate, it seemed to him, that 10° of cold, 22° below the freezing point of Fahrenheit, was a mild temperature. During the voyages made by Captain Parry and others to discover a northwest passage, it was found, that after having lived for some days in a temperature of 15° or 20° below 0, it felt comfortable when the thermometer rose to zero.

These are the great sources of the deceptive nature of our sensations as to warmth and cold which enable us to judge merely of the comparative conditions of the present and the past; and hence it is, that a deep cellar appears warm in winter and cold in summer. At a certain distance below the surface, the temperature of the earth indicates the medium heat of the climate; yet, although this may be stationary, our sensations on descending to it in winter and summer would be by no means the same. If two men were to meet on the middle of the South American Andes,—the one having descended, and the other ascended,—their sensations would be very different. The one, who had descended, coming from a colder to a warmer atmosphere, would experience warmth; whilst the other, who had ascended, would feel correspondently cool. An experiment, often performed in the chemical lecture-room, exhibits the same physiological fact. If, after having held one hand in iced, and the other in warm water, we plunge both into water of a medium heat, it will seem warm to the one hand, and cold to the other.

But our sensations are not guided solely by bodies surrounding us. They are often greatly dependent, especially in disease, on the state of the animal economy itself. If the power, which the system possesses, of forming heat, be morbidly depressed,—or if, in consequence of old age, or of previous sickness, calorification does not go on regularly

[1] Reise des kaiserlich Russischen Flotten Lieutenants F. v. Wrangel längs der Nordküste von Siberien, u. s. w., Berlin, 1839, translated in Harper's Family Library.

and energetically, a temperature of the air, which to the vigorous is agreeable, may produce an unpleasant impression of cold. Under opposite circumstances, a feeling of heat exists.

In regard to the mode in which the temperature of bodies is appreciated, there are peculiarities, which would favour the idea of the sense of heat being distinct from that of tact or touch. Professor Weber, for example, found that the left hand is more sensitive than the right, although the sense of touch is more acute in the latter; and that if the two hands, at the time of like temperature, be plunged into separate basins of water, the one in which the left hand is, will appear to be the warmer, even although its temperature may be somewhat lower than that of the other. It would seem, too, from Weber's experiments, that in regard to sensations of heat and cold, a weaker impression made upon a large surface appears more powerful than a stronger made upon a small surface; and, accordingly, to judge of nice shades of difference in the temperature of a fluid, the whole hand will enable a variation to be detected, that would be inappreciable to the finger. A difference of one-third of a degree, it is affirmed, may be easily detected, when the same hand is placed successively in two vessels of water, or any other fluid.[1]

These and other phenomena of an analogous kind have led to the suggestion, that every nerve of sensation is composed of several nerves, each of which may have its special function; and that the nerves of touch comprise some which appreciate temperature; others, which perceive the resistance of bodies, and others which effect touch properly so called. In proof of this a recent writer urges that either of these faculties may be lost, without the other being so. Thus, when the arm has been "asleep," and sensibility is returning to it, the hand first perceives temperature, then the resistance of bodies, and it is not until some time afterwards that the faculty of touch, properly so called, is exercised. In the lower extremities the contrary takes place; the sense of touch first returns; then a sensation of pricking is experienced, followed by the perception of temperature, and the power of appreciating resistance returns last. It may be added, that many cases are recorded, in which the sense of temperature has been lost, whilst the ordinary sense of tact remained; and, as remarked by Dr. Carpenter,[2] it is an additional evidence in favour of the distinctness of nervous fibres to convey the impressions of temperature, that these are frequently affected,—a person being sensible of heat or of chilliness in some part of the body,—without any real alteration of its temperature, whilst there is no corresponding affection of the tactile sensations.

By tact we are likewise capable of forming a judgment of many of the qualities of bodies,—such as their size, consistence, weight, distance, and motion. This faculty, however, is not possessed exclusively by the sense in question. We can judge of the size of bodies by the sight; of distance, to a certain extent, by the ear, &c. To appreciate these characters, it is necessary, that the sense should be used actively; that we should call into exercise the admirable instrument with which

[1] E. H. Weber, art. Tastsinn und das Gemeingefühl, in Wagner's Handwörterbuch der Physiologie, 22te Lieferung, S. 549, Braunschweig, 1849.

[2] Principles of Physiology, 2d Amer. edit., p. 229, Philad., 1845.

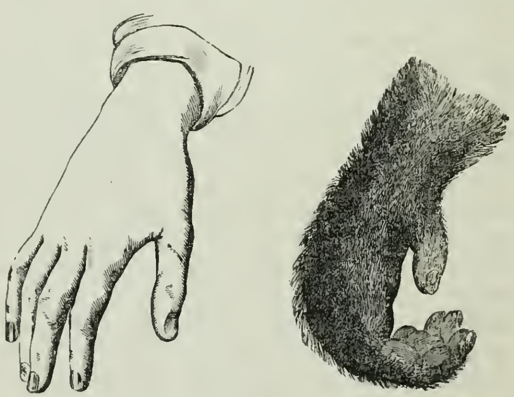
we are provided for that purpose; and in many of them we are greatly instructed by the muscular sense.

In treating of the external senses generally, it was remarked, that we are capable of judging, by their aid, of impressions made on us by portions of our own body. By the sense of touch we can derive information regarding its temperature, shape, consistence, &c. An opinion has, indeed, been advanced, that this sense is best adapted for proving our own existence, as every time that two portions of the body come in contact, two impressions are conveyed to the brain, whilst if we touch an extraneous body, there is but one.

The tact of mucous membranes is extremely delicate. The great sensibility of the lips, tongue, tunica conjunctiva, Schneiderian membrane, lining membrane of the trachea and urethra, is familiar to all. Excessive pain is produced in them by the contact of extraneous bodies; yet, in many cases, they signally exemplify the effect of habit in blunting sensation. The first introduction of a bougie into the urethra generally produces intense irritation; but after a few repetitions the sensation may become scarcely disagreeable.

To appreciate accurately the shape and size of objects, it is necessary, that they should be embraced by a part of the body, which can examine their surfaces, and be applied to them in every direction. In man, the organ well fitted for this purpose is the hand. This is situate at the free extremity of a long and flexible member, which admits of its being moved in every direction, and renders it not only well adapted for the organ of touch, but for that of prehension. Man alone possesses a true hand; for although other animals have organs of prehension very similar to his, they are much less complete. Aristotle and Galen termed it the *instrument of instruments*, and its construction was considered worthy of forming the subject of one of the "*Bridgewater Treatises*" "On the Power, Wisdom, and Goodness of God, as manifested in the Creation,"—a task assigned to Sir Charles Bell.

Fig. 234.



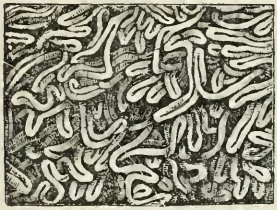
Hand of Man, compared with anterior extremity of Orang.

The chief superiority of the hand consists in the size and strength of the thumb, which stands out from the fingers, and can be brought in opposition to them, so as to enable us to grasp bodies, and to execute various mechanical processes under the guidance of the intellect. So important was the thumb esteemed by Albinus,[1] that he called it a lesser hand to assist the larger—"*manus parva majori adjutrix*."

[1] De Sceleto, p. 465.

In addition to the advantages referred to, the hand is furnished with a highly sensible integument. The papillæ are largely developed, especially at the extremities of the fingers, where they are ranged in concentric circles, and rest upon a spongy tissue, by many considered to be erectile, and serving as a cushion, and are well supplied with capillary vessels. (See Figs. 217, and 235.) At the posterior extremity of the fingers, are the nails, which support the pulps of the fingers behind; and render the contact with external bodies more immediate. This happy organization of the soft parts of the hand alone concerns the sense of touch directly. The other advantages, which it possesses, relate to the power of applying it under the guidance of volition.

Fig. 235.



Capillary Network at margin of lips.

Of the mode in which touch is effected it is not necessary to treat. Being nothing more than tact, exerted by an appropriate instrument, the physiology of the two must be identical.

Metaphysicians have differed widely regarding the services that ought to be attributed to the touch. Some have greatly exaggerated them, considering it *the sense par excellence*, the *first of the senses.* It is an ancient notion to ascribe the superiority of man over animals and his pre-eminence in the universe—his intelligence, in short—to the hand. Anaxagoras asserted, and Helvetius[1] revived the idea, "that man is the wisest of animals because he possesses hands." The notion has been embraced and expanded by Condillac,[2] Buffon,[3] and many modern physiologists and metaphysicians. Buffon assigned so much importance to the touch, that he believed the cause why one person has more intellect than another is his having made a more prompt and repeated use of his hands from early infancy. Hence, he recommended, that infants should use them freely from the moment of birth. Other metaphysicians have considered the hand the source of mechanical capabilities; but the same answer applies to all these views. It can only be regarded as an instrument by which information of particular kinds is conveyed to the brain; and by which other functions are executed, under the direction of the will. The idiot often has the sense more delicate than the man of genius or than the best mechanician, whilst the most ingenious artists have by no means the most delicate touch. We have, indeed, some striking cases to show, that the hand is not entitled to this extravagant commendation. Not many years ago, a Miss Biffin was exhibited in London, who was totally devoid of upper and lower extremities; yet she was unusually intelligent and ingenious. It was surprising to observe the facility with which she hem-stitched; turning the needle with the greatest rapidity in her mouth, and inserting it by means of the teeth. She painted miniatures faithfully, and beautifully;—holding the pencil between her head and neck. All her

[1] De l'Homme, &c., tom. i.
[2] Traité des Sensations, P. i.
[3] Histoire Naturelle, tom. vi.

motions were, in fact, confined to the tongue and lips, and to the muscles of the neck. M. Magendie[1] alludes to a similar case. He says, that there was, in Paris, at the time he wrote, a young artist, who had no signs of arm, forearm, or hand, and whose feet had one toe less than usual—the second; yet his intelligence was in no respect inferior to that of boys of his age; and he even gave indications of distinguished ability. He sketched and painted with his feet. Not many years ago, a Miss Honeywell, born without arms, travelled about this country. She had acquired so much dexterity in the use of the scissors, as to be able, by holding them in her mouth, to cut likenesses, watch-papers, flowers, &c. She also wrote, drew, and executed all kinds of needle-work with the utmost ease and despatch. How fatal are such authentic examples to the views of Helvetius and others!

But, it has been said, that touch is the least subject to error of all the senses: it is the *regulating*—the *geometrical* sense. In part only is this accurate. It certainly possesses the advantage of allowing the organ of sense to be brought into immediate contact with the body that excites the impression; whilst, in the case of olfaction, the organ receives the impression of an emanation from the body; and, in vision and audition, only the vibration of an intervening medium. Yet some of the errors into which touch falls are as grievous as those that happen to the other senses. How inaccurate is its appreciation of the temperature of bodies! We have attempted to show, that it affords merely relative knowledge,—the same substance appearing hot or cold to us, according to the temperature of the substance previously touched. Nay, infallibility so little exists, that we have the same sensation communicated by a body that rapidly abstracts caloric from us, as by one that rapidly supplies it. By touching frozen mercury, which requires a temperature of —40° of Fahrenheit to be congealed, we experience the sensation of a burn. Again, if we cross the fingers and touch a rounded body—a marble, for instance—with two of the pulps at the same time: instead of experiencing the sensation of one body, we feel as if there were two,—an illusion produced by the lateral portions of fingers being brought in apposition, which are naturally in a different situation, and at a distance from each other; and, as these two parts habitually receive distinct impressions when separated, they continue to do so when applied to opposite sides of the rounded body.

It has been asserted, that the touch is the great corrector of the errors into which the other senses fall. But let us inquire, whether, in this respect, it possesses any decided superiority over them. For this purpose, the distinction of the sensory functions into *immediate* and *mediate* has been adopted. Each sense has its immediate function, which it possesses exclusively; and for which no other can be substituted. The touch instructs us regarding resistance; the taste appreciates savours; the smell, odours; audition, sound; and vision, colours. These are the *immediate* functions of the senses, each of which can be accomplished by its own organs, but by no other. As concerns the immediate functions of the senses, therefore, the touch

[1] Précis Élémentaire, 2de édit., i. 154, Paris, 1825.

can afford no correction. Its predominance, as regards the *mediate* functions of the senses, is likewise exaggerated. The *mediate* functions are those that furnish impressions to the mind; and by aid of which it acquires its notions of bodies. The essential difference between these two sets of functions is, that the mediate can be effected by several senses at once, and may be regarded as belonging to the cerebrum. Vision, olfaction, and audition participate with touch in enabling us to judge of distances; the sight instructs us regarding shape, &c. It has been affirmed by metaphysicians, that touch is necessary to several of the senses to give them their full power, and that we could form no notion of the size, shape, and distance of bodies, unless instructed by this sense. The remarks already made have proved the inaccuracy of this opinion. The farther examination of it will be resumed under Vision. The senses are, in truth, of mutual assistance. If the touch falls into error, as in the case of inaccurate appreciation of temperature, the sight, aided by appropriate instruments, dispels it. If the crossed fingers convey to the brain the sensation of two rounded bodies, when one only exists, the sight apprises us of the error; and if the sight and touch united impress us with a belief in the identity of two liquids, the smell or the taste will often detect the erroneous inference.

But, it has been said by some, touch is the only sense that gives us any notion of the existence of bodies. M. Destutt-Tracy[1] has satisfactorily opposed this, by showing that such notion is a work of the mind, in acquiring which the touch does not assist more immediately than any other sense. "The tactile sensations," he observes, "have not of themselves any prerogative essential to their nature, which distinguishes them from others. If a body affects the nerves beneath the skin of my hand, or if it produces certain vibrations in those distributed on the membranes of my palate, nose, eye, or ear, it is a pure impression which I receive; a simple affection which I experience; and there seems to be no reason for believing that one is more instinctive than another; that one is more adapted than another for enabling me to judge that it proceeds from a body exterior to me. Why should the simple sensation of a puncture, burn, titillation, or pressure, give me more knowledge of the cause, than that of a colour, sound, or internal pain? There is no reason for believing it." There are, indeed, numerous classes of bodies, regarding whose existence the touch affords us no information, but which are detected by the other senses.

On the whole, then, we must conclude, that the senses mutually aid each other in the execution of certain of their functions; that each has its province, which cannot be invaded by others; and that too much preponderance has been ascribed to the touch by metaphysicians and physiologists. Ministering, however, as it does, so largely to the mind, it has been properly ranked with vision and audition as an intellectual sense.[2]

By education, the sense of touch is capable of acquiring extraordi-

[1] Élémens d'Idéologie, 1ère Partie, p. 114, 2de édit. Paris, 1804.
[2] Gall, Sur les Fonctions du Cerveau, i. 99, Paris, 1825.

nary acuteness. To this circumstance must be ascribed the surprising feats we occasionally meet with in the blind. For all their reading and writing they are, indeed, indebted to this sense, and modelling in clay, wax, &c., and sculpture, carving in wood, and even engraving have been accomplished by them.[1]

Dr. Saunderson—who lost his eyesight in the second year of his life, and was Professor of Mathematics at Cambridge, England—could discern false from genuine medals; and had a most extensive acquaintance with numismatics.[2] As an instance of the correct notions, which may be conveyed to the mind of the forms and surfaces of a great variety of objects, and of the sufficiency of these notions for accurate comparison, Dr. Carpenter[3] mentions the case of a blind friend, who has acquired a very complete knowledge of conchology, both recent and fossil; and who is not only able to recognize every one of the numerous specimens in his own cabinet, but to mention the nearest alliances of a shell previously unknown to him, when he has thoroughly examined it by the touch. Baczko, referred to by Rudolphi,[4] who describes his own case, could discriminate between samples of woollen cloth of equal quality but of different colours. The black appeared to him among the roughest and hardest: to this succeeded dark blue and dark brown, which he could not, however, distinguish from each other. The colours of cotton and silk stuffs he was unable to discriminate; and he properly enough doubts the case of a Count Lynar, blind, who, it was said, was capable of judging of the colour of a horse by the feel. The only means the blind can possess of discriminating colours must be through the physical differences of surface, which render it capable of reflecting one ray or combination of rays, whilst it absorbs the rest; and if these differences were insufficient to enable Baczko to detect the differences between cotton and silk fabrics, it is not probable, that the sleek surface of the horse would admit of such discrimination.[5] Education or sustained and discriminating attention gives the same facility in the appreciation of temperature. It is affirmed, that Dr. Saunderson, when some of his pupils were engaged in taking the altitude of the sun, could tell by the slight modification in the temperature of the air, when very light clouds were passing over the sun's disk.

The deaf have no perception of the vibrations of sonorous bodies; yet by the sense of touch they can judge of tangible percussions from bodies that are thrown into powerful vibration; and Dr. Kitto[6]—himself deaf—has given a vivid representation of the impression made upon him by different forms of percussive vibrations.

[1] Rev. Wm. Taylor, F. R. S., in Notices of the Meetings of the Royal Institution, 1853.

[2] Abercrombie's Inquiries concerning the Intellectual Powers; Amer. edit., p. 55, New York, 1832.

[3] Principles of Human Physiology, American edit., p. 657, Philad., 1854; and art. Touch, Cyclop. of Anat. and Physiol., iv. 1180, Lond., 1852.

[4] Grundriss der Physiologie, 2er Band, S. 85, Berlin, 1823.

[5] For an interesting account of the blind and deaf James Mitchell, Laura Bridgman, and others, referred to hereafter—and of blind travellers, blind poets, blind musicians, blind divines and blind philosophers, see The Lost Senses, by John Kitto, D. D., F. S. A., Series II., Blindness, Lond., 1845.

[6] Op. cit., Series I., Deafness, Lond., 1853.

In animals the organ of touch varies. The monkey's resembles that of man. In other quadrupeds, it is seated in the lips, snout, or proboscis. In molluscous animals, the tentacula; and in insects, the antennæ or feelers, are organs of touch, possessing, in some, very great sensibility. Bats appear to have this to an unusual degree. Spallanzani observed them, even after their eyes had been destroyed and the ears and nostrils closed, flying through intricate passages, without striking the walls, and dexterously avoiding cords and lines placed in the way. The membrane of the wings is, in the opinion of Cuvier and many others,[1] the organ that receives an impression produced by a change in the resistance of the air. M. Jurine concludes, that neither hearing nor smell is the channel through which they obtain perception of the presence and situation of surrounding bodies. He ascribes this extraordinary faculty to the great sensibility of the skin of the upper jaw, mouth, and external ear, which are furnished with large nerves; whilst Sir Anthony Carlisle attributes it to the extreme delicacy of hearing possessed by the animal;[2] a view which is confirmed by experiments instituted by the author's friend, Professor J. K. Mitchell. Certain experiments by Mr. Broughton[3] sanction the idea that this may be, in part, dependent upon their whiskers. These, which are found on the upper lip of feline and other animals, are plentifully supplied with nerves, which seem to proceed from the second branch of the fifth pair, and are lost in the substance of the hairs. In an experiment, made by Mr. Broughton on a kitten, he found that whilst the whiskers were entire, it was capable of threading its way, blindfold, from a labyrinth in which it was designedly placed; but it was totally unable to do so when the whiskers were cut off. It struck its head repeatedly against the sides; ran against all the corners; and tumbled over steps placed in the way, instead of avoiding them, as it did prior to the removal of the whiskers.

From facts like these Mr. Broughton drew the conclusion, that certain animals are supplied with whiskers for the purpose of enabling them to steer clear of opposing bodies in the dark.

B. SENSE OF TASTE OR GUSTATION.

The sense of taste teaches us the quality of bodies called *sapidity*. It is more nearly allied to touch in its mechanism than any other of the senses, as it requires the immediate contact of the body with the organ, and the organ is, at the same time, capable of receiving tactile impressions distinct from those of taste. Of this we have a striking example, if we touch various portions of the tongue with the point of a needle. We find two distinct perceptions occasioned. In some parts the sensation of a pointed body without savour; and in others, a metallic taste is experienced. Pathological cases, too, exhibit, that the sense of taste may be lost, whilst general sensibility remains, —and conversely. The organ of gustation is not, therefore, restricted to that sense, but participates in touch. Yet so distinct are those functions, that touch can, in no wise, supply the place of its fellow

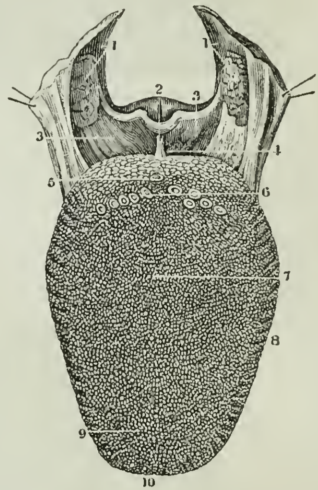
[1] Carpenter, Human Physiology, p. 253, Lond., 1842.
[2] See Roget's Animal and Vegetable Physiology, ii. 399, Amer. edit., Philad., 1836.
[3] London Medical and Physical Journal, for 1823.

sense, in detecting the sapidity of bodies. This last is the *immediate* instruction afforded by gustation.

1. ANATOMY OF THE ORGANS OF TASTE.

The chief organ of taste is the tongue, or rather the mucous membrane covering the upper surface, and sides of that organ. The lips, inner surface of the cheeks, palate, and fauces, participate in the function, especially when particular savours are concerned. M. Magendie[1] includes the œsophagus and stomach; but we know not on what grounds: his subsequent remarks, indeed, controvert the idea. The lingual branch of the fifth pair is, according to him, incontestably the nerve of taste; and, as this nerve is distributed to the mouth, we can understand, why gustation should be effected there; but not how it can be accomplished in the œsophagus and stomach. The tongue consists almost entirely of muscles, which give it great mobility, and enable it to fulfil the various functions assigned to it; for it is not only an organ of taste, but of mastication, deglutition, and articulation. The muscles being under the influence of volition, enable the sense to be executed passively or actively.

Fig. 236.

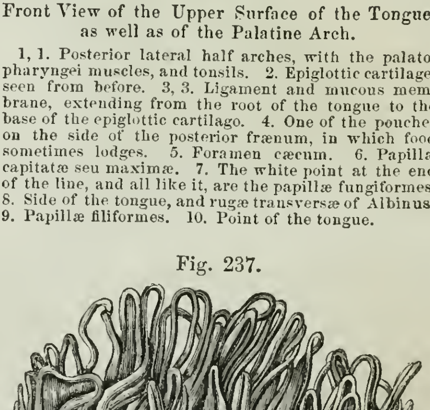


Front View of the Upper Surface of the Tongue, as well as of the Palatine Arch.

1, 1. Posterior lateral half arches, with the palato-pharyngei muscles, and tonsils. 2. Epiglottic cartilage, seen from before. 3, 3. Ligament and mucous membrane, extending from the root of the tongue to the base of the epiglottic cartilage. 4. One of the pouches on the side of the posterior frænum, in which food sometimes lodges. 5. Foramen cæcum. 6. Papillæ capitatæ seu maximæ. 7. The white point at the end of the line, and all like it, are the papillæ fungiformes. 8. Side of the tongue, and rugæ transversæ of Albinus. 9. Papillæ filiformes. 10. Point of the tongue.

As regards gustation, the mucous membrane is the portion immediately concerned. This is formed, like the mucous membranes in general, of the different layers already described. The corpus papillare requires farther notice. If the surface of the tongue be examined, it will be found to consist of myriads of fine papillæ or villi, that give the organ a velvety appearance. These papillæ are, doubtless, like those of the skin,

Fig. 237.

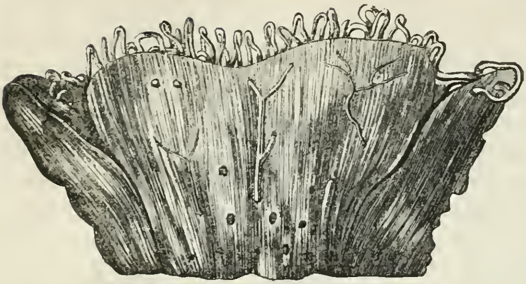


View of a Papilla of the smallest class, magnified 25 diameters.

The loops o blood-vessels are here shown, each loop containing usually only one vessel.

[1] Précis de Physiol., i. 139.

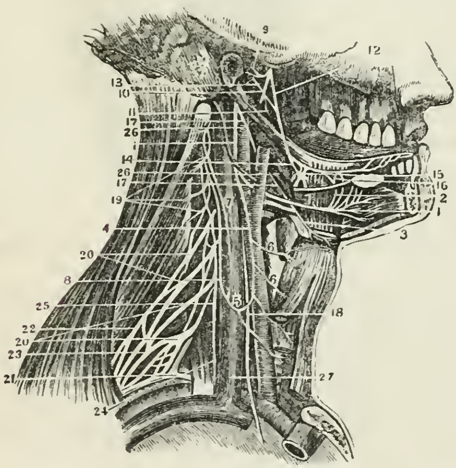
Fig. 238.



Vertical Section of one of the Gustatory Papillæ of the largest class, showing its conical form, its sides, and the fissure between the different Papillæ.

The length of some of the divided blood-vessels, a transverse section of others, and the vessels which rise up from the surface like loops or meshes, are also shown.

Fig. 239.



The Hypoglossal; Lingual branch of fifth pair: Glosso-Pharyngeal and deep-seated Nerves of the Neck.

1. The hypoglossal nerve. 2. Branches communicating with the lingual branch. 3. A branch to the origin of the hyoid muscles. 4. The descendens noni nerve. 5. The loop formed with the branch from the cervical nerves. 6. Muscular branches to the depressor muscles of the larynx. 7. A filament from the second cervical nerve, and 8, a filament from the third cervical, uniting to form the communicating branch with the loop from the descendens noni. 9. The auricular nerve. 10. The inferior dental nerve. 11. Its mylo-hyoidean branch. 12. The lingual branch. 13. The chorda-tympani passing to the lingual branch. 14. The chorda-tympani leaving the lingual branch to join the sub-maxillary ganglion. 15. The sub-maxillary ganglion. 16. Filaments of communication with the lingual nerve. 17. The glosso-pharyngeal nerve. 18. The pneumogastric or par vagum nerve. 19. The three upper cervical nerves. 20. The four inferior cervical nerves. 21. The first dorsal nerve. 22, 23. The brachial plexus. 24, 25. The phrenic nerve. 26. The carotid artery. 27. The internal jugular vein.

formed of the final ramifications of nerves, and of the radicles of exhalant and absorbent vessels, united by means of a spongy erectile tissue. Great confusion exists among anatomists in their descriptions of the papillæ of the tongue. Those certainly concerned in the sense of taste may, however, be included in two divisions:— 1st, the *conical* or *pyramidal*,—the finest sort by some called *filiform;* and 2dly, the *fungiform.* The former are broader at the base than at the top; and are seen over the whole surface of the tongue, from the tip to the root. The latter, which are larger at the top than the base, and resemble the mushroom, —whence their name, —are spread about, here and there, on the surface of the organ. These must be distinguished from a third set, the *papillæ capitatæ* or *circumvallatæ*, which are situate near the base of the tongue in two V shaped lines at the base of the organ. They are circular elevations from $\frac{1}{20}$th to $\frac{1}{12}$th of an inch wide, each with a central depression, and surrounded by a circular fissure, at the outside of which, again, is a slightly elevated ring, the central elevation and the ring being formed of close set simple papillæ. The epithelium of the tongue is of the tesselated variety, like that of the epidermis. Over the fungiform papillæ, it forms a thinner layer than elsewhere; so that they stand out more prominently than the rest. That which covers the conical papillæ, according to Messrs. Todd and Bowman,[1] has a singular arrangement; being extremely dense and thick, and projecting from their sides and tops in the form of long, stiff, hair-like processes; many of which bear a strong resemblance in structure to hairs; and some actually contain hair tubes.

All the nerves that pass to the parts whose office it is to appreciate savours, must be considered to belong to the gustatory apparatus. These are the inferior maxillary; several branches of the superior; filaments from the spheno-palatine and naso-palatine ganglions; the lingual branch of the fifth pair, commonly called the *gustatory* nerve; the whole of the ninth pair or hypoglossal; and the glosso-pharyngeal. To which of these must be assigned the function of gustation, we shall inquire presently.

Like the skin and mucous membranes in general, that of the tongue and mouth contains, in its substance, numerous mucous follicles, which secrete a fluid that lubricates the organ, and keeps it in a condition adapted for the accomplishment of its functions. The fluids, exhaled from the mucous membrane of the mouth, and the secretion of the different salivary glands, likewise aid in gustation; but they are more concerned in mastication and insalivation, and will require notice under another head.[2]

2. SAVOURS.

Before proceeding to explain the physiology of gustation, it may be necessary to inquire briefly into the nature of bodies as connected with their sapidity; or, in other words, into *savours*, which are the cause of sapidity.

The ancients were of opinion, that the cause of sapidity is a peculiar principle, which, according to its combination with the constituents of bodies, gives rise to various savours. This notion has been long abandoned; and chiefly, because we observe no general or common characters amongst sapid bodies, which ought to be were they pervaded by the same principle; and because bodies may be deprived of their sapidity by subjecting them to appropriate processes. Many of our culinary processes have been instituted for this purpose: the infusion of tea is indebted for all its attractions to the power we possess of separating, by boiling water, the savoury from the insipid portions of the plant. A sapid principle must, therefore, be esteemed an integrant molecule of a body; not the same in all cases, but as heterogeneous in its nature as the impressions made upon the organ of taste.

When the notion was once entertained, that a sapid principle is an integrant molecule, sapidity was attempted to be explained by its shape. It was said, for instance, that if the savour be sweet, the molecule must be round; if sharp, angular; and so forth. Sugar was said to possess a spherical,—acids, a pointed, or angular molecule. We

[1] The Physiological Anat. and Physiology of Man, i. 439, Lond., 1848, or Amer. edit., p. 382. See, also, H. Hyde Salter, art. Tongue in Cyclop. of Anat. and Physiol., iv. 1120, Lond., 1852.

[2] For an elaborate account of the Anatomy of the Organ of Gestation, see H. Hyde Salter, op. cit.

know, however, that substances which resemble each other in the primitive shape of their crystal, impress the organ of taste differently; and that solution, which must destroy most—if not all—the influence from shape, induces no change in the savour.

Others have referred sapidity to a kind of chemical action between the molecules, and the nervous fluid. This view has been suggested by the fact, that, as a general rule, sapid, like chemical bodies, act only when in a state of solution; that the same savours usually belong to bodies possessed of similar chemical properties, as is exemplified by the sulphates and nitrates; and that, in the action of acids on the tongue and mouth, we witness a state of whiteness and constriction, indicative of a first degree of combination. All these circumstances, however, admit of another explanation. There are unquestionably many substances, which do combine chemically,—not with a nervous fluid, of whose existence we know nothing,—but with the mucus of the mouth; and the sapidity resulting from such combination is appreciated by the nerves of taste; but there are many bodies, which are eminently sapid, and yet afford us instances of very feeble powers of chemical combination; nay, in numerous cases, we have not the least evidence that such powers exist. Vegetable infusions or solutions are strong examples of the kind,—of which syrup may be taken as the most familiar. The effect of solution is easily intelligible; the particles of the sapid body are in this way separated, and come successively into contact with the gustatory organ; but there is some reason to believe, that solution is not always requisite to give sapidity. Metals have generally a peculiar taste, which has been denominated *metallic;* and this, even if the surface be carefully rubbed, so as to free it from oxide, which is more or less soluble. Birds, too, whose organs of taste are as dry as the corn they select from a mass of equally arid substances, are probably able to appreciate savours. The taste produced by touching the wires of a galvanic pile with the tongue has been offered as another instance of sapidity exhibited by dry bodies. This is, more probably, the effect of chemical action on the fluids covering the mucous membrane of the tongue, which always follows such contact. Such chemical change must, however, be confined to these fluids; and, when once produced, the nerve of taste is impressed by the savour developed in the same manner as it is in cases of morbid alterations of the secretion of the mucous membrane. In both cases, a body possessing considerable and peculiar sapidity may fail to impress the nerves altogether, or may do so inaccurately. The notion of any chemical combination with the nervous fluid must of course be discarded, as there is not the slightest evidence in favour of the hypothesis; yet the epithet *chemical* was once applied to this sense on the strength of it; in opposition to the senses of touch, vision, and audition, which were called *mechanical*, and supposed to be produced by vibrations of the nerves of those senses.

The savours, met with in the three kingdoms of nature, are innumerable. Each body has its own, by which it is distinguished: few instances occur in which any two can be said to be identical. This is the great source of difficulty, when we attempt to throw them into classes, as has been done by physiologists. Of these classifications, the one by Linnæus[1] is best known: it will elucidate the unsatisfactory character of the whole. He divides sapid bodies into *sicca*, *aquosa*, *viscosa*, *salsa*, *acida*, *styptica*, *dulcia*, *pinguia*, *amara*, *acria*, and *nauseosa*. He gives also examples of mixed savours, *acido-acria*, *acido-amara*, *amaro-acria*, *amaro-acerba*, *amaro-dulcia*, *dulci-styptica*, *dulci-acida*, *dulci-acria*, and *acri-viscida;* and remarks, that the majority are antitheses to each other, two and two,—as *dulcia* and *acria; pinguia* and *styptica; viscosa* and *salsa;* and *aquosa* and *sicca*. Boerhaave[2] again divides them into *primary* and *compound;* the former including the *sour*, *sweet*, *bitter*, *saline*, *acrid*, *alkaline*, *vinous*, *spirituous*, *aromatic*, and *acerb;*—the latter resulting from the union of certain primary savours. There is no accordance amongst physiologists as to those that should be esteemed primary, and those secondary and compound; although the division appears to be admissible. The *acerb*, for example—which is considered primary by Boerhaave—is by others, with more propriety, classed among *secondary* or *compound*, and believed to consist of a combination of the acrid and acid. We understand, however, sufficiently well the character of the *acid*, *acrid*, *bitter*, *acerb*, *sweet*, &c.; but when, in common language, we have to depict other savours, we are frequently compelled to take some well-known substance as a standard of comparison.

According to M. Adelon,[3] the only distinction we can make amongst them is,—into the *agreeable* and *disagreeable*. Yet of the unsatisfactory nature of this classification he himself adduces numerous proofs. It can only, of course, be applicable to one animal species, often even to an individual only; and often again only to such individual when in a given condition. Some animals feed upon substances, that are not only disagreeable but noxious to others. The most poisonous plants have an insect which devours them greedily and with impunity: the southern planter is well aware, that this is the case with his tobacco, unless the operation of *worming* be performed in due season. The old adage, that "one man's meat is another man's poison" is metaphorically accurate. Each individual has, by organization or association, dislikes to particular articles of food, or shades of difference in his appreciation of tastes, which may be esteemed peculiar; and, in certain cases, these peculiarities are signal and surprising.

Of the strange differences, in this respect, that occur in the same individual under different circumstances, we have a forcible instance in the pregnant female, who often ardently desires substances, that were previously perhaps repugnant to her, or, at all events, not relished. The sense, too, in certain diseases—especially of a sexual character, or such as are connected with the state of the sexual functions—becomes strangely depraved, so that substances, which can in no way be ranked as eatables, are greedily sought after. A young lady was under the care of the author, whose *bonne bouche* was slate pencils. In other cases, we find chalk, brickdust, ashes, dirt, &c., preferred. Habit, too, has considerable effect in our decisions regarding the agreeable. The Roman liquamen or garum, the most celebrated sauce of antiquity, was prepared from half putrid intestines of fish; and one of the varieties

[1] Amœnit. Academ., ii. 335. [2] Prælect. Academ., tom. iv.
[3] Physiologie de l'Homme, seconde édit., i. 301, Paris, 1829.

of the Οπος Σιλφιον, *laserpitium*, is supposed to have been assafœtida.[1] Even at this day, certain orientals are fond of the flavour of this nauseous substance. Putrid meat is the delight of some nations; and a rotten egg, especially if accompanied with the chick, is esteemed by the Siamese. In civilized countries, we find game, in a putrescent state, eaten as a luxury: this, to those unaccustomed to it, requires a true education. The same may be said of the pickled olive, and of several cheeses—*fromage de Gruyère*, for example—so much esteemed by the inhabitants of continental Europe.

M. Magendie[2] asserts, that the distinction of savours into agreeable and disagreeable is the most important,—as substances whose taste appears agreeable to us are generally useful; whilst those whose taste is disagreeable are commonly noxious. As a general rule this is true, but there are many signal exceptions to it.

3. PHYSIOLOGY OF TASTE.

The physiology of taste being so nearly allied to that of touch effected by mucous membranes, it will not be necessary to repeat the uses of the various layers of which the membrane of the mouth consists. In order that taste may be satisfactorily executed, it is necessary that the membrane should be in a state of integrity; for if the cuticle be removed, gustation is not effected; and the morbid sensation of pain is substituted. It is also indispensable that the fluids poured into the cavity of the mouth should be in necessary quantity, and possess proper physical characteristics. We can farther appreciate the advantages of mastication and insalivation, by which solid bodies are divided into minute portions; dissolved when soluble, and brought successively in contact with the organ of taste. The gustatory nerves thus receive the impression, and by them it is transmitted to the brain. These nerves go to the formation of the papillæ, which, we have seen, are situated in a spongy, erectile tissue. As in the sense of tact and touch, it is probable that this erectile tissue is not passive during the exercise of taste; and that the papillæ, through it, assume a kind of erection. M. Magendie[3] believes this view to be void of foundation; but Sir C. Bell[4] has properly remarked, that if we take a pencil, dip it in a little vinegar, and touch, or even rub it strongly on the surface of the tongue, where these papillæ do not exist, the sensation of the presence of a cold liquid is alone experienced; but if we touch one of the papillæ with the point of the brush, and, at the same time, use a magnifying glass, it is seen to stand erect, and the acid taste is felt to pass, as it were, backward to the root of the tongue. This experiment confirms the one with the point of the needle before referred to, and shows that the parts of the tongue which possess the power of receiving tactile impressions are distinct from those concerned in gustation. The fine conical papillæ, by some called *filiform*, seated at the sides and tip of the tongue, have been generally esteemed the most exquisitely sensible.

[1] See an article on the Gastronomy of the Romans, by the author, in Amer. Quarterly Review, ii. 422, Philad., 1827.

[2] Précis Elémentaire, i. 139.

[3] Précis, &c., i. 141.

[4] Anatomy and Physiol., Godman's 5th Amer. edit., ii. 283, New York, 1827.

The sense of taste is almost wholly accomplished in the membrane covering the tongue.[1] M. A. Vernière[2] found, in experiments which he instituted, the mucous membrane of the palatine arch, gums, cheeks, lips, and middle and dorsal region of the tongue constantly insensible to savours; whilst gustatory sensibility was possessed by the membrane covering the sublingual glands, the inferior surface, point, edges and base of the tongue; the pillars and two surfaces of the velum palati, the tonsils and pharynx. Subsequently, MM. Guyot and Admyrauld[3] found, from a series of experiments made upon themselves, that the lips, inner surface of the cheeks, palatine arch, pharynx, pillars of the velum palati, and dorsal and inferior surface of the tongue are incapable of appreciating savours; and that the seat of gustation is at the posterior and deep-seated part of the tongue, beyond a curved line, whose concavity anteriorly passes through the foramen cæcum, and joins the two margins of the tongue anterior to the pillars;—at the edges of the tongue; and on a surface of about two lines uniting them with the dorsal surface;—at the apex with an extension of four or five lines on the dorsal, and of one or two on the inferior surface; and lastly, at a small space of the velum palati situate nearly at the centre of its anterior surface. M. Guyot, moreover, found, that the same sapid body does not produce the same sensation on every part of the gustatory organ. We find, indeed, that certain bodies affect one part of the mouth, and others another. Acids act more especially on the lips and teeth; acrid bodies, as mustard, on the pharynx. These experiments were repeated by M. Longet,[4] with every precaution pointed out by MM. Vernière, Guyot, and Admyrauld. The results agreed generally with those of M. Vernière. He could not, however, discover any gustatory sensibility in the mucous membrane covering the superior surface of the velum palati, the sublingual glands, and inferior surface of the tongue; and he does not regard the superior and middle region of the tongue as absolutely devoid of gustatory sensibility.

That the sense is not restricted to the tongue we have direct evidence in those cases in which the tongue has been wanting. M. Roland, of Saumur,[5] gives the case of a child, six years of age, who lost the organ in smallpox; and yet could speak, spit, chew, swallow, and taste. De Jussieu[6] exhibited to the *Académie des Sciences* of Paris, in 1718, a Portuguese girl, born without a tongue, who also possessed these faculties. In a case mentioned by M. Berdot, and cited by Rudolphi,[7] in which no part of the tongue existed, the individual could appreciate the bitterness of sal ammoniac; and the sweetness of sugar; and Blumenbach[8] refers to that of a young man, who was born without a

[1] Bidder, art. Schmecken, in Wagner's Handwörterbuch der Physiologie, 13ste Lieferung, S. 2, Braunschweig, 1846.
[2] Journal des Progrès, &c., iii. 208, and iv. 219, Paris, 1827.
[3] Mémoire sur la Siége du Goût chez l'Homme, Paris, 1830, and Archives Générales de Médecine, Janvier, 1837.
[4] Traite de Physiologie, tom. ii. p. 166, Paris, 1850.
[5] Aglossostomographie, Paris, 1630.
[6] Mém. de l'Académ. des Sciences, p. 6, Paris, 1718.
[7] Grundriss der Physiologie, 2ter Band, 1ste Abtheil., S. 92, Berlin, 1823.
[8] Comparative Anatomy, by Lawrence, p. 323, London, 1807.

tongue; and yet, when blindfolded, could distinguish between solutions of salt, sugar, and aloes, put upon the palate.[1]

Certain bodies leave their taste in the mouth for a length of time after they have been swallowed. This *arrière-goût*—Nachgeschmack of the Germans—is sometimes felt in the whole mouth; at others, in a part only; and is probably owing to the papillæ having imbibed the savour,—for the substances producing the effect belong principally to the class of aromatics. This imbibition frequently prevents the savour of another substance from being duly appreciated: and, in the administration of nauseous drugs, we avail ourselves of the knowledge of the fact, either by previously giving an aromatic so as to forestall the nauseous impression, or, by combining powerful aromatics with it, which strongly impress the nerves, and produce a similar result.

There is a common experiment, which has been the foundation of numerous wagers, and elucidates this subject; or at least demonstrates, that the effect produced upon the nerve by the special irritant continues, as in the case of the other senses, for some time after it has made its impression, so that the nerve becomes, for a time, comparatively insensible to the action of other sapid bodies. It consists in giving to one—blindfold—brandy, rum, and gin, or other spirituous liquors in rapid succession, and seeing whether he can discriminate one from another. A few contacts are sufficient to impregnate the nerve so completely that distinction becomes confounded.

It has been remarked, that numerous nerves are distributed to the organ of taste: the ninth pair, the lingual, and other branches of the fifth, and the glosso-pharyngeal. (See Fig. 239.) An interesting question arises—which of these is the nerve of taste; or are more than one, or the whole, concerned? Of old, the lingual nerve of the fifth pair was universally considered to accomplish the function; the other nerves being looked upon as simple motors. Boerhaave and others assigned the office to the ninth, and considered the others to be motors. The filaments of the fifth have been described as traceable even in the papillæ; but others have denied this. Opinions have generally settled down upon the lingual branch of the fifth pair. Such is the view of Sir Charles Bell, who considers the *ninth pair*, which arises from the anterior column of the spinal marrow, the nerve of motion for the tongue; the *lingual branch of the fifth*, a nerve having a posterior root, the nerve of taste; and the *glosso-pharyngeal*, the nerve by which the tongue is associated with the pharynx in the function of deglutition. Bellingeri[2] thinks the last nerve gives the organic and involuntary character to the tongue. In this it is aided by branches of the fifth pair and pneumogastric. The hypoglossal he regards as the nerve of the voluntary motions of the organ for articulate speech, and modulated sound in singing—an inference which has seemed to be confirmed by the fact, that in fishes (*pisces muti*) it is wanting. It is likewise maintained, that the fifth is the first encephalic nerve, which appears in the lower classes of animated nature; as the taste is the first of the

[1] Brillat Savarin, Physiologie du Goût, p. 38, Paris, 1843.

[2] Dissert. Inaugural. Turini, 1823, noticed in Edinburgh Med. and Surg. Journal for July, 1834, p. 129.

special senses noticed in them; that, at first, the nerve consists only of the lingual branch; and farther, that its size, in animals, is generally in a ratio with that of the organs of taste and mastication.

Certain experiments by M. Magendie[1] would seem to settle the question definitely. On dividing the lingual branch of the fifth pair on animals, he found that the tongue continued to move, but that they lost the faculty of appreciating savours. The palate, gums, and internal surface of the cheeks, however, preserved the faculty, because supplied with other branches of the fifth. But when the trunk of the nerve was cut within the cranium, the power of recognising savours was completely lost in every part of the mouth,—even in the case of highly acrid and caustic bodies. He found, too, that the loss of sense occurred in all those who had the fifth pair morbidly affected,—a fact, which has been confirmed by observations of others.[2]

Experiments on dogs by Professor Panizza, of Pavia, led him to infer, that the hypoglossal is the nerve of motion for the tongue; the lingual branch of the fifth pair, the nerve of general sensibility; and the glosso pharyngeal, the nerve of gustation.[3] The views of Panizza have been embraced by Messrs. Elliotson,[4] Wagner,[5] Valentin, Bruns, Broughton,[6] and others,[7] and have been confirmed by the experiments and observations of Stannius;[8] and Mr. Broughton has summed up what he considers to be the final results of all the comparative inquiries. The communicating nerve of the face (portio dura), and the fifth pair, arising by distinct roots, send off branches as they emerge from the bed of the parotid gland, some of which unite in parallel lines, and others do not, each ramification retaining the original property of its own root unmixed; the one destined to govern certain motions of different parts of the face; the other devoted to tactile sensibility, as far as regards the superficial parts of the face. Thus far, there is no disagreement: the whole developement has been arrived at by repeated experiments by different persons. In the next place, it appears, that the hypoglossal governs the motions of the tongue; deglutition; and mastication, without interfering with common sensation and taste. The instinctive and voluntary motions of the tongue are all destroyed by dividing this nerve. The next position is, that the lingual branches of the fifth pair are devoted to tactile sensibility, or the common sensation of the tongue. Their division does not affect the motions of that organ

[1] Précis., i. 144, and Journal de Physiologie, t. iv.

[2] Mr. Bishop, in Lond. Med. Gazette for Dec. 12, 1835; and Romberg, Müller's Archiv., 1838, H. iii.

[3] Richerche Sperimentali sopra i Nervi, translated in Edinb. Med. and Surg. Journal, for Jan., 1836, p. 70; see also, Amer. Journal of the Med. Sciences, May, 1836, p. 188; and Mayo, Outlines of Human Physiology, 4th edit., p. 314, London, 1837.

[4] Human Physiology, p. 536, Lond. 1840.

[5] Trait· de Névrologie, trad. par Jourdan, p. 433, Paris, 1843, and Lehrbuch der Physiologie des Menschen, ii. 679. Braunschweig, 1844.

[6] Edinburgh Medical and Surgical Journal, April, 1836, p. 431. A case in which there was complete insensibility of every part supplied by the fifth pair, and the sense of taste was perfect, is given in Bullet. dell Scienz. Medich., Aprile, 1841, cited in Brit. and For. Med. Rev., Oct., 1842, p. 545. See, also, Bidder, Art. Schmecken, in Wagner's Handwörterbuch der Physiologie, loc. cit.

[7] Funke, Lehrbuch der Physiologie des Menschen, von A. F. Günther, B. ii., Abth. 2, S. 359, Leipz., 1853.

[8] Müller's Archiv., S. 132–138, Berlin, 1848.

or its power of taste; both remain entire. Lastly, when the glosso-pharyngeal nerve is divided, the sense of taste is lost; whilst, the other nerves being uninjured, motion and tactile sensibility remain. Professor Panizza found, that when the glosso-pharyngeal nerve was divided, the animal could not taste coloquintida.

From a series of experiments, however, similar to those of Panizza and Mr. Broughton, Mr. Mayo inferred, in conformity with an opinion previously expressed by him,[1] that the lingual branch of the fifth is the proper nerve of taste, and that it possesses also general sensibility; that the ninth or hypoglossal is the nerve of voluntary motion; whilst the glosso-pharyngeal is in part a nerve of voluntary motion and in part of general sensibility, but not of taste.[2] Again: the experiments and researches of Dr. John Reid,[3] have satisfied him, that after the perfect section of the glosso-pharyngeal nerves on both sides, the sense of taste is sufficiently acute to enable the animal to recognise bitter substances; and his inference is, that this nerve may participate with others in the function of taste; but that it assuredly is not the special nerve of that sense. Prof. J. Müller[4] esteems it certain, both from his own experiments and those of M. Magendie and others, as well as from pathological observations, that the lingual branch of the fifth is the principal nerve of taste of the tongue; but he does not regard it proved, that the glosso-pharyngeal has no share in the perception of taste at the posterior part of the tongue, and in the fauces. Dr. Carpenter,[5] from a consideration of how nearly the sense of taste is allied to that of touch, and bearing in mind the distribution of the two nerves, thinks it not difficult to arrive at the conclusion, that both nerves are concerned in the function;[6] and that there seems good reason to believe the glosso-pharyngeal to be exclusively that through which the impressions made by disagreeable substances taken into the mouth are propagated to the medulla oblongata, so as to produce nausea, and excite efforts to vomit;—whilst M. Longet[7] regards the lingual branch of the fifth and the glosso-pharyngeal as necessary for the general and special sensibility of the gustatory organs, "the action of the one perfecting that of the other, both as respects the general sensibility and the gustatory sensibility of the tongue." It may be proper to add, that experiments seem to show, that the glosso-pharyngeal possesses also a direct motor influence. Such is the inference of Messrs. J. Müller, Volkmann, and Hein. The last observer, whose experiments were carefully performed, states that his results accord completely with those of Volkmann. When the roots of the glosso-pharyngeal nerve were irritated in the recently cut-off heads of calves and dogs, after removing the brain and medulla

[1] Anatomical and Physiological Commentaries, p. 2, Lond., 1822.

[2] Bostock's Physiology, 3d edit., p. 732, Lond., 1836; and Mayo, Outlines of Physiology, 4th edit., p. 314, Lond., 1837.

[3] Edinburgh Medical and Surg. Journal, for Jan., 1838, p. 129. See, on this disputed topic, Alcock, in Dublin Journal, for Nov., 1836, and J. Guyot, Archives Générales de Médecine, Janvier, 1837.

[4] Elements of Physiology, by Baly, P. v. p. 1321, Lond., 1839.

[5] Human Physiology, p. 173, and p. 253, Lond., 1842, and Art. Taste, in Todd's Cyclop. of Anat. and Physiol., iv. 858, Lond., 1852.

[6] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 442, London, 1845.

[7] Traité de Physiologie, ii. 297, Paris, 1850.

oblongata, and separating their roots from those of the pneumogastric, contractions always ensued in the stylo-pharyngeus muscle. From all the facts adduced by recent observers, Mr. Paget[1] thinks it probable,—*First.* That the glosso-pharyngeal is chiefly the nerve of taste, and, in a less degree, a nerve of common sensation; and *Secondly.* That, according to the experiments of MM. Müller and Hein, it is the motor nerve of the stylo-pharyngeus, and probably also of the palato-glossus.

Lastly, M. de Blainville supposes, that the sense of taste is, perhaps, neither sufficiently special nor sufficiently limited in extent to have a separate nervous system; and therefore that all the afferent nerves of the tongue are equally inservient to the sense, as the different nerves of the skin, which proceed from numerous pairs, are equally inservient to touch or tact.[2]

Such is the existing state of uncertainty regarding this interesting point of physiology; the view of Panizza appears, however, to the author, to be most in accordance with analogy; and in all respects most worthy of adoption.

From the experiments and observations of Bellingeri, Montault, Diday, C. Bernard, and Verga,[3] it would appear, that the filaments of the chorda tympani, which are united and confounded with those of the lingual branch of the fifth pair, are in an inexplicable manner connected with gustation. When the facial nerve has been paralyzed, or divided above the origin of the tympanic branch, the sense of taste has been impaired. The functions of the chorda tympani are by no means determined;—some esteeming it as a sensory, others as a motor nerve; whilst others, again, believe it to possess both sensory and motor properties.

The immediate function of taste, as has been remarked, is to give the sensation of savours. This function, like touch, is instinctive; requires no education; cannot be supplied by any of the other senses, and is accomplished as soon as the tongue has acquired the necessary degree of development. To this it may be replied, that the very young infant is not readily affected by savours. In all cases, however, certain sapid bodies excite their usual impression; and, in the course of a few months, when the organ becomes developed, the sense acquires a high, and often inconvenient, degree of acuteness.

The mediate or auxiliary offices of gustation are few, and limited in extent. It does not afford much instruction to the mind. The chemist and mineralogist occasionally gain information through it; but it is never considered to merit the rank of an *intellectual* sense: on the contrary, it is classed with olfaction as a *corporeal* sense.

To appreciate a savour accurately, the sapid substance must remain for a time in the mouth; when rapidly swallowed, the impression is feeble, and almost null. Of this fact we take advantage when compelled to swallow nauseous substances; whilst we retain a savoury article long in the mouth, in order that we may extract its sweets. How different, too, is the consent of the auxiliary organs under these two

[1] Brit. and For. Med. Rev., April, 1845, p. 580.
[2] Adelon, op. cit., i. 309. [3] Cited by M. Longet, op. cit., p. 365, Paris, 1850.

circumstances! Whilst a luscious body augments the secretion of the salivary glands, or causes the "mouth to water," as it has been called —projecting the saliva, at times, to a distance of some feet from the mouth, and disposing every part to approach or mingle with it—a nauseous substance produces constriction of every secretory organ; an effect which extends even to the stomach itself, so that it often rejects the offending article, as soon as it reaches the cavity. We can thus understand how, *cæteris paribus*, an article, that is pleasing to the palate, may be more digestible than one that excites disgust; and conversely. Of the "consent of parts," exerted between the stomach and the organ of taste, we have a familiar illustration in the fact,—that whatever may be the *goût*, with which we commence a meal on a favourite article of diet, we find that the relish is blunted as the stomach becomes filled; and hence the Romans were in the habit of leaving the table once or twice during a meal, and, after having unloaded the organ, of returning again to the charge—"*vomunt ut edant, edunt ut vomant.*"

If we place a sapid substance in the mouth, and then close the nostrils, the taste is diminished,—a fact, which has given rise to the generally prevalent and correct opinion, that an intimate relation exists between the smell and taste. They are, however, distinct. Most sapid substances have an odour or "flavour," which is not appreciated when we prevent the air from passing through the nasal fossæ. This renders the impression on the gustatory nerves still less marked, but it exists. Gustation is likewise diminished by the new sensation produced in the nostrils by their closure; so that the same amount of attention is not directed to the sense of taste.

A curious case of deprivation and modification of the senses of taste and smell has been related by Mr. Justice,[1] of Philadelphia. It shows the intimate relation between them. Nine months previously, a person of his acquaintance was thrown from his carriage; and in the fall, his head came first in contact with the ground, and concussion of the brain was produced. The injury appeared to have been received behind, but above the ear. He was laid in bed in a state of total insensibility, and thus remained for nearly a month, about which time he revived, and, to his surprise, found that he had entirely lost both the sense of taste and the sense of smell. In this situation he remained at the time when Mr. Justice detailed the particulars of the case. It was equally indifferent to him what he took as food so far as regarded taste,—Cayenne pepper or sawdust as he expressed it being alike tasteless;—but as a compensation for this privation, he had a constant sensation of a most delightful character, which he could only compare to that of the most delicious cordial flowing through his mouth. This continues night and day, and is especially perceptible when the lips are apart, and he inhales the air through his mouth;—the only intermission to this pleasurable sensation being whilst he is taking his food.

Yet although closely related the senses of taste and smell are distinct. A case has been related by Dr. J. C. Hutchinson[2] in which the olfactory nerve appeared to be entirely paralyzed, whilst the branches

[1] Proceedings of the American Philosophical Society, vi. 52, Oct. 6, 1854.
[2] American Journal of the Medical Sciences, Jan., 1852.

of the fifth pair retained their integrity. Smell was lost; yet a pungent sensation was excited by irritating vapours, and when snuff was taken sneezing was induced. The sense of taste, however, did not seem to be modified; inasmuch as substances, which were possessed of neither smell nor pungency could be readily distinguished from each other, even when their tastes were not very different.

Among animals we see great diversities in this sense. Whilst none possess the refined taste of man, there are many, which are capable, by taste or smell, of knowing plants that are nutritive from those that are noxious to them; and it is unusual for us to find that an animal has died from eating such as are unquestionably poisonous to it. Yet, as we have remarked, a substance, that is noxious to one, may be eaten with impunity by another; and, if we select animals, and place them in a field containing plants, all of which are ranked as poisons, and are poisonous to a majority of them, we find that not only has a selection been made by each animal of that which is innocuous to it, but that the substance has furnished nourishment to it, whilst it might have proved fatal to others. All this must be dependent upon peculiar, and inappreciable organization.

The sense of taste is more under the influence of volition than any other. It is provided with a muscular apparatus, by which it can be closed or opened at pleasure; and, in addition, ordinarily requires the assistance of the upper extremity to convey the sapid substance to the mouth. The sense can, therefore, be exercised either *passively* or *actively;* and, by cultivation, it is capable of being largely developed. The spirit taster to extensive commercial establishments exhibits the truth of this in a striking manner. In his vocation, he has not only to taste numerous samples, but to appreciate the age, strength, flavour, and other qualities of each; and the practised individual is rarely wrong in his discrimination. With almost all, if not all, these "tasters," the custom is to take a small quantity of the liquor into the mouth; throw it rapidly around that cavity, and eject it. A portion, in this way, comes in contact with every part of the membrane; and of course impresses the glosso-pharyngeal as well as the lingual and other ramifications of the fifth pair.

The *gourmet* of the French—somewhat more elevated in the scale than our ordinary epicure—prides himself upon his discrimination of the nicest shades of difference and excellence in the materials set before him. Many *gourmets* profess to be able to pronounce, by sipping a few drops of wine, the country whence it comes, and its age; and, according to Stelluti, can tell, by the taste, whether birds put upon the table are domesticated or wild,—male or female.[1] Dr. Kitchener[2] asserts, that many epicures are capable of saying in what precise reach or stretch of the Thames the salmon on the table has been caught; and Sir Astley Cooper was in the habit of relating the remarkable case of a professional friend, who could discriminate by the taste the beef furnished by a particular London butcher.[3] This acuteness of sense is

[1] American Quarterly Review, ii. 427.

[2] Cook's Oracle, 3d edit., p. 229, Lond., 1821.

[3] Life of Sir Astley Cooper, Bart., by Bransby Blake Cooper, Esq., F. R. S., ii. 137, Lond., 1843.

by no means desirable. Doomed to meet, in his progress through life, with such a preponderance of what demands obtuseness rather than acuteness of feeling, the epicure must be liable to continual annoyances and discomforts, which the less *favoured* can never experience.

In disease, gustation often becomes greatly depraved; and the various morbid tastes have been accounted for by depraved secretions in the mouth, acting as foreign sapid substances on the papillæ. Certain tastes, however, cannot be explained in this way, and must be regarded as nervous phenomena—subjective sensations. If the epithelium be covered with a fur, taste may be lost or impaired, and be instantaneously restored as soon as the coating is removed. M. Magendie observed, that dogs, after the injection of milk into their veins, licked their lips, and gave other evidences of tasting. When Dr. E. Hale, in an experiment referred to in another part of this work, injected castor oil into one of his veins, he distinctly tasted the oil a short time afterwards. Messrs. Todd and Bowman[1] suggest that such phenomena, if uniformly present, might be occasioned by the transudation of the fluid from the vessels to the nerves of the papillæ; and this may be the true explanation, although it is not so easy to see that such transudation could readily occur in the case of castor oil.

C. SENSE OF SMELL OR OLFACTION.

The object of this sense is to appreciate the odorous properties of bodies. It differs from the last in the circumstance that the body does not come into immediate contact. It is only necessary that an odorous emanation from it shall impinge upon the organ of sense. Still, it does not essentially vary in its physiology from the sense of taste.

1. ANATOMY OF THE ORGAN OF SMELL.

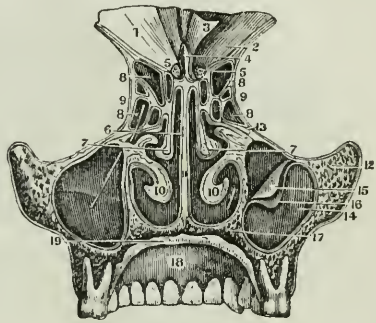
The organ of smell is a mucous membrane, which lines the nasal cavities, and is called *Schneiderian* or *pituitary*. It resembles that which covers the organ of taste, except that the nervous papillæ are more delicate, to correspond with the greater tenuity of the body that has to make the impression. The membrane lines the whole of the bony cavities called *nasal fossæ*, which are constantly open anteriorly and posteriorly, to permit the air that traverses them to proceed to the lungs. The anterior aperture is covered by a kind of pent-house or capital, for the purpose of collecting the odorous particles. This capital is called the *nose*. The essential part of the organ is the pituitary or olfactory membrane,—the other parts being superadded to perfect the sense.

The bony portions of the nose are separated from each other by the *vomer*. This bony septum is prolonged, by means of cartilage, to the anterior extremity of the nose, so that the nasal fossæ are divided into like parts, which have no communication with each other, but open together, posteriorly, into the top of the pharynx. Within each of the nares are two *convoluted* or *turbinated bones*—generally called *ossa spongiosa* seu *turbinata;* and, by the French, *cornets*. These are situate

[1] The Physiological Anatomy and Physiology of Man, p. 448, Lond., 1845.

one above the other; the *superior* formed of a plate of the ethmoid bone—the inferior a distinct bone. They divide the general cavity of each nostril into three *passages* or *meatus*. The *inferior* meatus is broad and long; the least oblique, and least tortuous; the *middle* is narrow, almost as long, but more extensive from above to below; and the *superior* is much shorter, more oblique, and still narrower. The narrowness of these passages in the living subject is so great, that the slightest tumefaction of the membrane renders the passage of air through the fossæ extremely difficult. This is the cause of the difficulty of breathing through the nose, that attends "a cold in the head." Into the two upper passages, cavities in certain bones open, which considerably enlarge the extent of the fossæ. These are called *sinuses;* and are the *maxillary*, *palatine*, *frontal*, *sphenoidal*, *ethmoidal*,—the last being sometimes termed *ethmoidal cells.*

Fig. 240.



Vertical Section of the Middle Part of the Nasal Fossæ, giving a Posterior View of the Arrangement of the Ethmoidal Cells, &c.

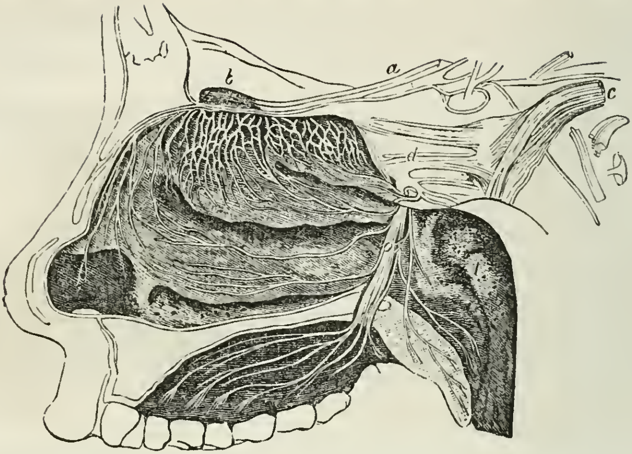
1. Anterior fossæ of the cranium. 2. The same covered by the dura mater. 3. Dura mater turued up. 4. Crista galli of the ethmoid bone. 5. Its cribriform plate. 6. Its nasal lamella. 7. Middle spongy bones. 8. Ethmoidal cells. 9. Os planum. 10. Inferior spongy bones. 11. Vomer. 12. Superior maxillary bone. 13. Its union with the ethmoid. 14. Anterior parietes of the antrum Highmoriaunm, covered by its membrane. 15. Its fibrous layer. 16. Its mucous membrane. 17. Palatine process of the superior maxillary bone. 18. Roof of the mouth, covered by the mucous membrane. 19. Section of this membrane. A bristle in the orifice of the antrum Highmorianum.

All the cavities are lined by the delicate pituitary membrane, or by a prolongation of it. In the nasal fossæ it augments the thickness of the turbinated bones. It resembles the mucous membranes in general in its composition; and adheres firmly to the bones and cartilages, which it covers. Its aspect is velvety, owing to a multitude of minute papillæ; and it receives a great number of vessels and nerves. The sinuses are lined by a prolongation apparently of the same membrane, differing, however, in some respects from the other. The whole of the membrane is the seat of the secretion of *nasal mucus*, which, doubtless, performs a part in olfaction as important as the secretion from the mucous membrane of the mouth does in gustation.

The same nerve is not distributed over the whole of this membrane. In some parts, the *olfactory*, *ethmoidal*, or *first pair* can be traced; in others, we see only filaments of the fifth pair. The first of these have not always been regarded as the nerves of smell. Anciently, they were presumed to be canals for the passage of pituita or phlegm, which was supposed to be secreted by the brain. At the present day, anatomists are doubtful only as regards their origin; some deriving them from the anterior lobes of the brain; others from the corpora striata, which have, in consequence, been called *thalami nervorum ethmoïdalium;* and others, again, with Willis and Gall,[1] and with probability,

[1] Recherches sur le Système Nerveux en général et sur celui du Cerveau en particulier, par F. J. Gall et G. Spurzheim, Paris, 1809.

Fig. 241.

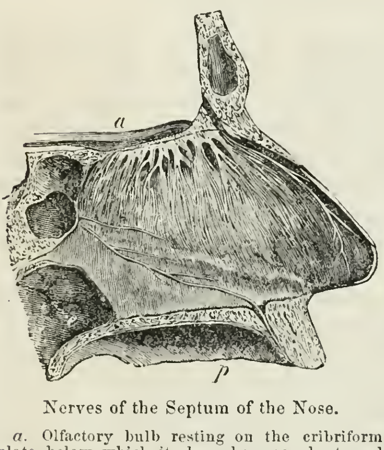


Outer wall of the Nasal Fossa, with the Three Spongy Bones and Meatus: the Nerves being shown as they would appear through the membrane if it were transparent.

a. Olfactory process. *b.* Olfactory bulb (represented rather too short) resting on the cribriform plate. Below is seen the plexiform arrangement of the olfactory filaments on the upper and middle spongy bones. *c.* Fifth nerve within the cranium with its Gasserian ganglion. *d.* Its superior maxillary division, sending branches to Meckel's ganglion, and through that to the three spongy bones, where they anastomose with the olfactory filaments, and with *s.* branches of the nasal division of the ophthalmic nerve. *o.* Posterior palatine twigs from Meckel's ganglion, supplying the soft and hard palate. *t.* Orifice of the Eustachian tube on the side of the pharynx, behind the lower spongy bone.—Two-thirds diameter.

referring them, like every other nerve of sense, to the medulla oblongata. M. Béclard affirms, that in a hydrocephalic patient, where a part of the brain had been destroyed by disease, he actually saw this origin.[1] The nerve proceeds directly forwards until it reaches the upper surface of the cribriform plate of the ethmoid bone, where it divides into a number of filaments, that pass through the foramina in the plate, and attain the nasal fossæ; where they are dispersed on the upper and middle part of the Schneiderian membrane; but cannot be traced on the lower. Most anatomists are of opinion, that here they constitute, with vessels of exhalation and absorption, the papillæ; whilst others, as Scarpa, not having been able to trace them thither, have been of opinion, that the filaments interlace to constitute a kind of proper membrane. Our means of observation cannot be considered sufficient to enable us to

Fig. 242.



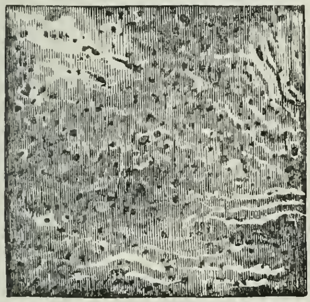
Nerves of the Septum of the Nose.

a. Olfactory bulb resting on the cribriform plate, below which its branches may be traced on the septum, about half way down. Behind, the naso-palatine nerve from Meckel's ganglion is seen descending to the naso-palatine canal. In front, the nasal twig of the ophthalmic nerve descends towards the tip of the nose, dividing into two principal branches. *p.* Roof of the mouth. *e.* Orifice of the Eustachian tube.—One-half diameter.

[1] Adelon, Physiologie de l'Homme, edit. cit., i. 330.

decide this question positively. The nerve has not been traced on the os spongiosum inferius; on the inner surface of the middle spongy bone, or in any of the sinuses.

Fig. 243.



A portion of the Pituitary Membrane of the Nasal Septum, magnified 9 times, showing the Number, Sizes, and Arrangement of the Mucous Crypts.

Fig. 244.

A portion of the Pituitary Membrane with its Arteries and Veins injected.—Magnified 15 diameters.

The natural size of this piece is seen at the bottom of the cut.
1, 1, 1. Orifices of three mucous crypts surrounded by veins and arteries.

The olfactory filaments, according to Messrs. Todd and Bowman,[1] form a considerable part of the entire thickness of the Schneiderian membrane, and differ widely from the ordinary encephalic nerves in structure. They contain no *white substance* of Schwann; are not divisible into elementary fibrillæ; are nucleated and finely granular in texture, and invested with a sheath of homogeneous membrane; and are regarded by those gentlemen as direct continuations of the vesicular matter of the olfactory bulb or ganglion; and they "venture to hint," that the amalgamation of the elements of the peripheral part of the nervous apparatus in the larger branches, and probably in the most remote distribution, as well as the nucleated character indicative of an essential continuity of tissue with the vesicular matter of the lobe, are in accordance with the oneness of the sensation resulting from simultaneous impressions on different parts of this organ of sense, and seem to show, that it would be most correct to speak of the first pair of nerves as a portion of the nervous centre put forward beyond the cra-

Fig. 245.

Olfactory Filaments of the Dog.

a. In water. *b.* In acetic acid.—Magnified 250 diameters.

[1] Op. cit., ii. 5–11.

nium, in order that it may there receive, as at first hand, the impressions of which the mind is to become cognizant.

Besides the first pair of nerves, the pituitary membrane receives several branches from the fifth encephalic pair; for example, the nasal twig of the ophthalmic branch of the fifth, and filaments from the frontal branch of the same; from the spheno-palatine ganglion; the palatine nerve; the vidian nerve; and from the anterior dental branch of the superior maxillary. One of these twigs enters the anterior naso-palatine canal; and, in its course to the roof of the mouth, passes through a small ganglion, which has been described by M. H. Cloquet under the name *naso-palatine*, and which he conceives to be the organ of sympathy between the senses of smell and taste.

The pituitary membrane is kept moist by nasal mucus, as well as by the exhalation that constantly takes place from it. It receives the superfluous tears by means of the ductus ad nasum,—a duct passing from the inner canthus of the eye, and opening into the nasal fossæ below the lower spongy bone. The constant evaporation which must take place from the membrane, owing to the passage of the air during respiration, requires that the secretion should be continuous and copious, otherwise the membrane would become dry.

The nasal fossæ communicate externally by means of the nostrils, the shape, size, and direction of which vary, so as to give rise to the *aquiline*, *Roman*, *pug*, and other varieties of nose. At the extremity of the nostrils long hairs are situate—technically called *vibrissæ*—whose function, it is conceived, may be to sift, as it were, the air passing through during respiration, and thus prevent extraneous bodies from entering the fossæ. The nostrils are also capable of being expanded or contracted by appropriate muscles.

In this sense, there is a more clear separation between the physical and nervous part of the apparatus than in either of those already considered;—the nose proper forming the physical portion; and the nerves of smell the organic or nervous.

2. ODOURS.

The comprehension of the physiology of olfaction will not be complete without an inquiry into *odours* or those emanations from odorous bodies, that give them their character, and impress the organ of smell.

It was long maintained, as in the case of savours, that odours are dependent upon a peculiar principle, which, according to its particular combination with the constituents of bodies, gives rise to various odours. To this principle the terms *aroma* and *spiritus rector* have been assigned; but the notion has been long abandoned, because no general or common characters are observable amongst odorous bodies, which should be expected were they indebted for their odour to the same principle. Walther, a German physiologist, expresses the opinion, that an odorous body is such by virtue of a vibratory motion, analogous to that made by a sonorous body. We have, however, the most satisfactory evidence, that there are special odours, as there are special savoury molecules. We can prevent an odorous body from impressing our olfactory nerves by covering it with a glass receiver. Odours can be separated by infusion and distillation. The fact, moreover, has been directly proved by an experiment of M. Berthollet. On nearly filling a tube with mercury, and placing a piece of camphor at the top of the tube, he found that, after a time, the mercury descended, the camphor had diminished in size, and the space above the metal was occupied by an odorous gas.[1]

But what is the cause of the disengagement of these odorous molecules? By most writers on this subject it has been considered to be owing to the solvent action of caloric on the odorous body. The opinion that all bodies are odorous is as old as Theophrastus; and it is one which it is difficult not to embrace, if we add—provided they are subjected to the appropriate agents for disengaging the odorous particles; and the probability is, that the reason we esteem particular bodies inodorous is, that our olfactory nerves are not organized with sufficient delicacy to enable us to distinguish their odorous properties. Heat assists the escape of odorous particles from a variety of bodies; and hence it has been maintained, that every body which is volatile must be odorous. M. Adelon[2] asserts, that this is not the case; but it is difficult to accord with him. The fact of our not appreciating the odour is no proof of its non-existence. In truth, bodies that are inodorous to one animal or individual may not be so to another. In cases, too, in which smell is morbidly acute, a substance may appear overwhelmingly odorous, which may seem devoid of smell to a healthy individual. M. H. Cloquet[3] refers to the case of a celebrated Parisian physician, who was subject to violent attacks of hemicrania or megrim, and who was dreadfully tormented, during one of the paroxysms, by the smell of copper, exhaled from a pin that had been dropped on the bed!

Caloric seems to be only one of the causes of the disengagement of odours. Some are retained by so feeble a degree of affinity, that they appear to be exhaled equally at all temperatures. Light influences their escape in particular cases; some plants giving off their fragrance during the day; others perfuming the air only at night. Dampness, in many instances, assists their escape,—hence the fragrance of a garden after a summer's shower; and the smell afforded by all argillaceous substances when breathed upon,—a fact, the knowledge of which is of importance to the chemist.

Lastly;—substances, that appear to us devoid of odour, may exhale a strong one, when rubbed together. All these circumstances tend greatly to prove, that every substance is possessed of odorous qualities, although we may not be aware of the precise mode for causing their emanation, or our olfactory nerves may not be sufficiently delicate to appreciate them.

Around odorous bodies, the molecules, as they escape, form an atmosphere, which, of course, will be denser, the nearer it is to the body. These particles are diffused around,—not, probably, in the same manner as light or sound, but as one fluid mixes with another; and, when the air is still, it is conceived, their strength will be inversely as the square of the distance from the substance that exhales them. There is a great difference, however, in odours as regards their diffusibility in

[1] Cloquet, Art. Odeurs, Dict. des Sciences Médicales, tom. xxxvii., p. 89, Paris, 1819.
[2] Op cit., i. 322.
[3] Osphrésiologie ou Traité des Odeurs, Paris, 1821.

the atmosphere. Some extend to a great distance, whilst others are confined within a small compass. The odours of many flowers are so delicate as not to be appreciated, unless they are brought near the olfactory organs; whilst that of cinnamon is said to have been detected at sea, at the distance of twenty-five miles from Ceylon. Lord Valentia[1] affirms, that he himself distinctly smelt the aromatic gale at nine leagues' distance;—but Dr. Ruschenberger[2] was not equally fortunate. The author was informed by Commodore Stewart, of the Navy, that he had discovered the spicy emanations when two hundred miles from Ceylon, and the terebinthinate odours of the pines of Virginia, when one hundred miles from the coast; and Dr. Wilcocks, of Philadelphia, when at sea in 1844, and two hundred miles to the westward of the coast of Ireland, observed, as did many others of the passengers, a smoky odour, which lasted for several days in succession. On appealing to the captain for the cause of the phenomenon, he informed them that he had frequently remarked it before; and that it was owing to the long continuance of easterly winds, which carried the odour of burning peat from Ireland far out to sea.[3] Facts of this kind are employed by the natural philosopher to exhibit the excessive divisibility of matter. Scales, in which a few grains of musk have been weighed, have retained the smell for twenty years afterwards, although they must have been constantly exhaling odorous molecules during the whole of this period. Haller[4] kept some papers, for more than forty years, which had been perfumed by a single grain of amber; and, at the end of that time, they did not appear to have lost any of their odour. That distinguished physiologist and mathematician calculated, that every inch of their surface had been impregnated by $\frac{1}{2691064000}$th of a grain of amber, and yet they had scented for 14,600 days a stratum of air at least a foot in thickness. But how much larger must these molecules be than those of light—provided we regard it as consisting of molecules—seeing that glass is capable of arresting the former, but suffers the other to penetrate it in every direction.

Nor need we be so much surprised at the excessive diffusibility of odorous particles, when we call to mind the facts on record in regard to the transmission through the air of fine particles of sand. Generally, according to Mr. Darwin,[5] the atmosphere of the Cape Verd Islands is hazy; and this is caused by the falling of impalpably fine dust, which was found to have slightly injured the astronomical instruments. The morning before they anchored at Porto Praya, he collected a little packet of this brown-coloured fine dust, which appeared to have been filtered from the wind by the gauze of the vane at the mast-head. Sir Charles Lyell also gave him four packets of dust which fell on a vessel a few hundred miles northward of these islands. Pro-

[1] Voyages and Travels in India, London, 1809.

[2] Embassy to the courts of Muscat and Siam, &c., p. 154, Philad., 1838.

[3] Medical Examiner, March, 1846, p. 159.

[4] Elementa Physiolog., tom. v. lib. xiv. sect. 2, p. 157, Lausann., 1769.

[5] Journal of Researches into the Natural History and Geology of the countries visited during the voyage of H. M. S. Beagle round the world, &c. Amer. edit., i. 5. New York, 1846.

fessor Ehrenberg found, that this dust consisted, in great part, of infusoria with silicious shields, and of the silicious tissue of plants. In five little packets which Mr. Darwin sent him, he ascertained no less than sixty-seven different organic forms! The infusoria, with the exception of two marine species, were all inhabitants of fresh water.

Mr. Darwin has found no less than fifteen different accounts of dust having fallen on vessels when far out in the Atlantic. From the direction of the wind whenever it has fallen, and from its having always been observed during those months when the harmattan is known to raise clouds of dust high in the atmosphere, it is pretty certain that it must proceed from Africa. It is, however—as Mr. Darwin remarks—a singular fact, that, although Professor Ehrenberg is acquainted with many species of infusoria peculiar to Africa, he found none of these in the dust sent him; but, on the other hand, discovered in it two species which he knew as living only in South America. "The dust," says Mr. Darwin—"falls in such quantity as to dirty everything on board, and to hurt people's eyes; vessels even have run on shore owing to the obscurity of the atmosphere. It has often fallen on ships when several hundred, and even more than a thousand miles from the coast of Africa, and at points sixteen hundred miles distant in a north and south direction. In some dust, which was collected on a vessel three hundred miles from the land, I was much surprised to find particles of stone above the thousandth of an inch square, mixed with finer matter. After this fact, one need not be surprised at the diffusion of the far lighter and smaller sporules of cryptogamic plants. Dr. Kane[1] exhibited to the American Philosophical Society filaments of mosses sufficiently large to be recognized as such by the unassisted eye, which he had collected on the ice off Cape Adair, in the Arctic Seas, in the month of February, 1851, upwards of seventy miles from the shore.

The air is not the only vehicle for odours. It has been seen, that they adhere to solid bodies; and that, in many cases, they can be separated by aqueous or spirituous distillation. The art of the perfumer consists in fixing and preserving them in the most agreeable and convenient vehicles. Yet, it was at one time strenuously denied, that they could be conducted through water; and, as a natural consequence of this, that fishes could smell. M. Duméril, for example, maintained, that odours, being essentially of a volatile or gaseous nature, cannot exist in fluids;—and, moreover, that fishes have no proper olfactory organ;—that the part which is commonly considered in them to be such is the organ of taste. This opinion is entertained by few. We have seen that odours can be retained in fluids, and not many naturalists of the present day will be hardy enough to deny that fishes have an organ or sense of smell. At all events, few anglers, who have used the oil of rhodium, or other attractive bait, will be disposed to give up the results of their experience without stronger grounds than any that have been assigned by the advocates of that view of the subject. Besides, air is contained in considerable quantity in water, so that odorous substances might reach the olfactory organs through it.

[1] The U. S. Grinnell Expedition in search of Sir John Franklin: a personal narrative, by Elisha Kent Kane, M. D., U. S. N., p. 139. New York, 1853.

When it was determined, that odours consist in special molecules given off from bodies, it was attempted to explain their action on the pituitary membrane in the same manner as that of savours on the membrane of the tongue. It was conceived that the shape of the molecules of a pungent odour is pointed, that of an agreeable one, round. Others, again, were of opinion, that olfaction is owing to some chemical union between the odorous molecule and the nervous fluid, or between it and the nasal mucus. None, however, have attempted to specify the precise chemical composition that renders a body odorous. The sensations do not present the most favourable occasions for exhibiting chemical agency; and, in this particular sense, it is probably no farther concerned than in the sense of touch; and not so much as in that of taste. It is sufficient for the odorous particle—animal, vegetable, or mineral—to come in contact with the olfactory nerves, in order that the odour shall be appreciated; and we may, in vain, look for chemical action in many of those animal and vegetable perfumes,—as musk, amber, camphor, vanilla, &c.—which astonish us by their intensity and diffusibility.

The same remarks, that were made on the classification of savours, are applicable to that of odours. They are not less numerous and varied; and each substance, as a general rule, has its own, by which it is distinguished. Numerous attempts have been made to group them; but all have been unsatisfactory. The classification proposed by Linnæus,[1] was—into *Odores aromatici*, those of the flowers of the pink, bay leaves, &c.: *O. fragrantes*, those of the lily, jessamine, &c.; *O. ambrosiaci*, those of amber, musk, &c.; *O. alliacei*, those of garlic, assafœtida, &c.; *O. hircini*, (like that of the goat,) those of the *Orchis hircina*, *Chenopodium vulvaria*, &c.; *O. tetri*, *repulsive* or *virous odours*,—those of the greater part of the family *solaneæ;* and lastly, *O. nauseosi*, those of the flowers of the veratrum, &c. A simple glance at this division will exhibit its glaring imperfections. No two persons could agree to which of any two of the cognate classes a particular odour should be referred. None of the other classifications, that have been proposed, are more satisfactory. M. Fourcroy divided them into *extractive* or *mucous*, *fugaceous oily*, *volatile oily*, *aromatic* and *acid*, and *hydrosulphureous;*—and Lorry into *camphorated*, *narcotic*, *ethereal*, *volatile acid*, and *alkaline*. The distinction into *animal*, *vegetable*, and *mineral*, is not more commendable. Musk is the product of an animal of the ruminant family; but the odour is not confined to that animal. It is contained in the civet; in the flesh of the crocodile; and in the musk-rat. Haller asserts, that his own perspiration smelt of it. It is met with, likewise, in the vegetable kingdom:—in *Erodium moschatum*, in the seeds of *Abelmoschus*, the flowers of *Rosa moschata*, and *Adoxa moschatellina*, and in some of the varieties of the melon and pear; and, what is perhaps more surprising, in mineral substances;—as in certain preparations of gold; and in some earths of which tea-pots are made in China and Japan. The odour of garlic, again, is found not only in that vegetable, but in assafœtida; in arsenic, when thrown upon hot coals; and in *Bufo pluvialis*, a species of toad.

[1] Amœnitat. Academic., Erlang., 1787, 1790.

In by far the majority of cases, we can only designate an odour by comparing it with that of some well-known substance; hence the epithets *musky*, *alliaceous*, *spermatic*, &c. M. Adelon asserts, that the sole classification which can be adopted is into the *agreeable* and *disagreeable*. But even the miserably imperfect division proposed by Haller[1] is better than this: he made three classes—*Odores suaveolentes*, *O. medii*, and *O. fœtores*. The truth is, that all the objections, made to the division of savours into *agreeable* and *disagreeable*, are equally applicable to odours. Assafœtida, we have seen, was employed by the ancients as a condiment; and, although with us it has the name *devil's dung*, it is, by many of the Asiatics, called *food of the gods*. We find, too, certain animals that are almost enchanted by particular odours. The cat, for example, if catmint—*Nepeta cataria*,—or the root of valerian—*Valeriana officinalis*—be placed in its way. Again, odours, generally thought agreeable, are to some persons intolerable. To many, as to Professor Müller,[2] mignonette has but an herb-like odour. The smell of the calycanthus is to most individuals pleasant; but exceedingly disagreeable to some; and, according to Arnold,[3] whilst the flower of *Iris Persica* was pronounced to possess an agreeable odour by forty-one out of fifty-four persons, four considered it to have little scent; by eight it was declared to be devoid of odour, and by one to be disagreeable. These differences, like those in the appreciation of savours by animals, must be referred to minute and inappreciable differences of organization.

Odours have been considered to be possessed of medicinal and even of poisonous properties. Some individuals, whose peculiarity of constitution renders them very liable to the action of ipecacuanha or jalap, experience the emetic effects of the former, or the cathartic qualities of the latter, by merely smelling them for a short time; and the majority of individuals, by pounding jalap or rhubarb, find themselves sooner or later more or less affected. By smelling strong alcohol for a considerable time, intoxication may be induced, as not unfrequently happens to the spirit-taster, who is young in his vocation. It has also been asserted, that the constant application of this sense to the discrimination of teas in the English East India Company's warehouses has laid the foundation for numerous head affections; but the report originated in prejudice, or in accidental coincidences, and has not been found to be accurate.

In all cases in which we see medicinal or poisonous effects actually produced by substances inhaled through the nostrils, we cannot attempt to explain them by the simple impression made by the odorous particles on the olfactory nerves. They must be accounted for by minute particles of the medicinal or poisonous substance being diffused in the atmosphere, and coming in contact with the mucous membrane, through which they are absorbed, and in this manner enter the circulation.

Odours have, likewise, been considered to possess nutritive properties; and this, chiefly perhaps, from the effect known to be produced

[1] Elementa Physiolog., tom. v. lib. xiv. p. 162, Lausann., 1769.
[2] Elements of Physiology, by Baly, p. 1317, Lond., 1839.
[3] Physiology, ii. 561, cited by Dr. Carpenter, art. Smell, in Cyclopædia of Anatomy and Physiology, pt. xxxvi. p. 703, Lond., June, 1849.

by savoury smells upon the appetite. It is not probable, that absorption can occur to a sufficient extent to account for the apparent satiation. The fact can only be explained by the impression upon the nervous system, which influences the appetite materially, as we see in the effect of various mental emotions. The first impact of a nauseous odour, or even the view of a disgusting object, frequently converts the keenest appetite into loathing. Yet, anciently, it was believed, that life might be sustained for a time, by simply smelling nutritious substances. Democritus is said to have lived three days on the vapour of hot bread; and Bacon refers to a man who supported an abstinence of several days by inhaling the odour of a mixture of aromatic and alliaceous herbs. Two hundred years ago these notions were entertained to a great extent; and they suggested the viaticum for travellers proceeding to the moon, according to the plan proposed by Dr. John Wilkins, Bishop of Chester.[1] "If we must needs feed upon something," he remarks, "why may not smells nourish us? Plutarch and Pliny, and divers other ancients, tell us of a nation in India that lived only upon pleasing odours; and it is the common opinion of physicians that these do strangely both strengthen and repair the spirits." Fuller,[2] a learned cotemporary of the bishop affords an amusing instance of litigation, originally given by Rabelais,[3]—whom he does not cite, however, —arising from this supposed nourishing character of odours. A poor man being very hungry, stayed so long in a cook's shop who was dishing up the meat, that his stomach was satisfied with the smell thereof. The choleric cook demanded of him pay for his breakfast; the poor man denied having had any; and the controversy was referred to the decision of the next man that should pass by, who chanced to be the most notorious idiot in the whole city: he, on the relation of the matter, determined that the poor man's money should be put betwixt two empty dishes, and that the cook should be recompensed with the jingling of the money, as the man had been satisfied by the smell of the cook's meat.

It need scarcely be said, that if the vapour from alimentary substances be capable, in any manner, of serving the purposes of nutrition, it can only be by passing into the blood-vessels of the lungs.

3. PHYSIOLOGY OF OLFACTION.

In order that the sense of smell may be duly exercised, it is necessary that the emanation from an odorous body shall not only impinge upon the pituitary membrane, but that it shall do so with some degree of force. It must, in other words, be drawn in with the inspired air. Perrault[4] and Lower[5] found, that by making an opening into the tra-

[1] The Discovery of a New World, or a Disconrse tending to prove, that 'tis possible there may be another Habitable World in the Moon, with a Discourse concerning the possibility of a passage thither. Lond., 1638.

[2] Holy State, London, 1640.

[3] The Works of Francis Rabelais, ii. 115, Lond., 1849. In a note it is stated, "that Bocchoris, according to Plutarch, gave a similar judgment against the courtesan Thonis, who demanded in money the price of her favours from a young spark, who had enjoyed them in imagination only."

[4] Ess. de Phys., iii. 29.

[5] Needham, de Format. Fœtûs, p. 165; and Haller, edit. cit., v. 173.

chea of animals, and preventing the inspired air from passing through the nasal fossæ, smell was not effected; and that dogs, which were the subjects of the experiment, readily ate food they had previously refused.

These experiments were repeated by Professor Chaussier, and with like results.[1] They explain why we use effort to draw in air loaded with an odour that is agreeable to us; and, on the contrary, arrest the respiration, or make it pass entirely through the mouth when odours are disagreeable. Still they are occasionally so diffusible and expansible, that they reach, notwithstanding, the olfactory membrane; and we are compelled to shut them off by calling in the aid of the upper extremity. The air being the ordinary medium for the conveyance of odorous molecules, we can understand why the organ of smell should form a part of the air passages.

The use of the nose is to direct the air, charged with odours, towards the upper part of the nasal fossæ. Its situation is well adapted for the reception of emanations from bodies beneath it, and its appropriate muscles allow the nostrils to be more or less expanded or contracted. These uses assigned to the nose are demonstrated by the fact, that they, whose noses are deformed—especially the flat-nosed—or whose nostrils are directed forwards, instead of downwards, have commonly the sense feebly developed. The loss of the nose, too, either by accident or disease, has been found to destroy the sense completely; and by no means the least advantage of the rhinoplastic operation is the enjoyment afforded by the improvement of this sense. M. Béclard affirms, that an artificial nose, formed of paper or other appropriate materials, is sufficient to restore it, so long as the substitute is attached.[2] It is proper to remark, however, that in a case which fell under the author's observation, although the nose had been lost by syphilis, the smell persisted; and two cases of a similar kind occurred to M. P. H. Bérard.[3]

The mode in which olfaction is effected appears to be as follows:—The inspired air, loaded with odorous particles, traverses the nasal fossæ; and, in its passage, comes in contact with the pituitary membrane, through the medium of the nasal mucus. The use of this mucus seems to be, not only to keep the organ properly lubricated, but to arrest the particles as they pass,—not by any chemical attraction, but in a mechanical manner. The olfactory nerves being distributed on the membrane, receive the impression of the molecules, and, in this manner, sensation is accomplished.

The use of the different spongy or turbinated bones would seem to be to enlarge the olfactory surface. According to some, however, they form channels to direct the air towards the openings of the sinuses. The sinuses, themselves, afford subjects for physiological discussion. By many they are considered to add to the extent of olfactory surface: by others, to furnish the nasal mucus. No hesitation would be felt in pronouncing both the spongy bones and sinuses to be useful in olfaction, were it not that the olfactory nerves or first pair have not been traced on the pituitary membrane covering the middle and inferior spongy

[1] Adelon, op. cit., i. 335.
[2] Magendie, Précis Elémentaire, 2de édit., i. 136, Paris, 1825.
[3] Art. Olfaction, Dict. de Médecine, 2de édit., xxii. 9, Paris, 1840.

bones, or on that lining the different sinuses;—that the sinuses are wanting in the infant, which, notwithstanding, appreciates odours;—that they exist only in the mammalia;—and that experiments would seem to show, that the upper part of the olfactory organ is more particularly destined for the function, and that the sinuses, which, as well as the membrane covering the middle and lower spongy bones, are supplied by filaments from the fifth pair of nerves, are not sensible to odours.

Messrs. Todd and Bowman[1]—from the fact, that on the septum narium and turbinated bones bounding the direct passage from the nostrils to the throat, the lining membrane is rendered thick and spongy by the presence of ample and capacious submucous plexuses of both arteries and veins, of which the latter are by far the larger and more tortuous—surmise, and Dr. Carpenter[2] thinks, with much probability, that the chief use of these may be to impart warmth to the air, before it enters the proper olfactive portion of the cavity; as well as to afford a copious supply of moisture, which may be exhaled by the abundant glandulæ seated in the membrane. "The remarkable complexity of the lower turbinated bones in animals with active scent, without any ascertained distribution of the olfactory nerves upon them, has"—they remark—"given countenance to the supposition, that the fifth pair may possess some olfactory endowment, and seems not to have been explained by those who rejected that idea. If considered as accessory to the perfection of the sense in the way above alluded to, this striking arrangement will be found consistent with the view, which thus limits the power of smell to the first pair of nerves."

That the upper part of the nasal fossæ is the great seat of smell is proved by the facts referred to regarding the uses of the nose. Dessault mentions the case of a young female, who had a fistula in the frontal sinuses, and who could not perceive an odorous substance, when presented at the orifice of the fistula, because there was no communication with the proper portion of the nasal fossæ, although she was capable of breathing through the opening. M. Deschamps, the younger, relates the case of a man, who had a fistula of the frontal sinus, through which ether might be injected without its odour being appreciated, provided all communication had been previously cut off between the sinus and the upper part of the nasal fossæ; but if this precaution had not been taken, the sense was more vivid, when the odours passed through the fistulous opening, than when they reached the organ by the ordinary channel. Again;—M. Richerand[3] found that highly odoriferous injections, thrown through a fistulous opening in the maxillary sinus or antrum of Highmore, produced no olfactory sensation whatever.

All these facts would seem to lead to the belief, that the upper part of the nasal fossæ, on which the first pair or olfactory nerves are distributed, is the chief seat of olfaction, and that the inferior portions of these fossæ, as well as the different sinuses communicating with them, are not primarily concerned in the function; but, doubtless, offer secondary advantages of no little importance. This conclusion would,

[1] Physiological Anatomy and Physiology of Man, ii. 3.
[2] Art. Smell, Cyclop. of Anat. and Physiol., pt. xxxvi. p. 694, Lond., June, 1849.
[3] Elémens de Physiologie, édit. 13ème par Bérard, p. 202, Bruxelles, 1837.

however, seem to admit, what is not by any means universally admitted, that the olfactory is the sole or chief nerve of smell. Especially difficult is it to embrace this view, and not to believe that the spongy bones and sinuses on which the fifth pair are distributed, are agents in perfecting the sense, when we find them so largely developed in animals that possess unusual delicacy of smell, as the dog and elephant. It has already been remarked, that the ancients believed the olfactory nerves to be canals for conveying away the pituita or phlegm from the brain. Diemerbroeck, also, maintained this view.[1] At the early part of the last century, however, the olfactory was supposed to be the proper nerve of smell, and the opinion prevailed, with few dissentient voices, until within the last few years. Inspection of the origin and distribution of the nerve seems to indicate it as admirably adapted for special sensibility connected with smell. It is largely developed in animals in proportion to their acuteness of the sense, and is distributed on the very part of the pituitary membrane to which it is necessary to direct air, loaded with odorous emanations, in order that they may be appreciated. M. Magendie[2] has, however, endeavoured to show by experiment, that the sense of smell is in no wise, or little, dependent upon the olfactory nerve, but upon branches of the fifth pair. Prior to the institution of his experiments, he had observed with astonishment, that after he had removed the cerebral hemispheres, with the olfactory nerves of animals, they still preserved this sense. He had noticed, too, that it continued in lunatics, who had fallen into a state of stupor, and in whom the substance of the brain appeared, on dissection, greatly disorganized. These facts induced him to expose the olfactory nerves on living animals, and to experiment upon them; and he found, in the first place, that the nerves were insensible to puncture, pressure, and the contact of the most odorous substances. He afterwards satisfied himself, that after their division the pituitary membrane not only preserved its general sensibility, appreciated the contact of bodies, but also, strong odours, those of ammonia, acetic acid, oil of lavender, Dippel's oil, &c. On the other hand, having divided the fifth pair of nerves within the cranium, and left the olfactory nerves entire, he remarked, that the pituitary membrane had lost its general sensibility; was no longer sensible to contact of any kind; and had lost the power of appreciating odours. From these experiments, he considered himself justified in inferring, that the olfactory nerve does not preside over the general sensibility of the nose; that it has, at the most, a special sensibility as concerns odours; and that if the olfactory be the nerve of smell, it requires the influence of the fifth pair, in order that it may act. Lastly; he asks, may not the general and special sensibility be comprised in the same nerve in the sense of smell, as they are in that of taste;—in the fifth pair?

These experiments are interesting; but they by no means establish, that the fifth pair is *the* olfactory nerve. The numerous facts, already mentioned, attract us irresistibly to the first pair or *olfactory*, as they have been exclusively called. It has been already remarked, that the

[1] Anatome Corporis Humani, lib. iii. cap. 8, Ultraject., 1672.
[2] Précis Elémentaire, 2de édit., i. 132.

fifth is concerned in all the facial senses; that it conveys to them general sensibility or feeling; and that some of them are unquestionably supplied with nerves of special sensibility;—the eye with the optic; and the ear with the auditory; but that neither perhaps can fully exert its special functions, without the integrity of the fifth. The olfactory nerve is probably in this category,—is the nerve of special sensibility. It is true, that in the experiments of M. Magendie the animal appeared to be affected by odorous substances, after the division of the first pair; but a source of fallacy existed here, in discriminating accurately between the general and special sensibility. Some of the substances employed were better adapted for eliciting the former than the latter;—ammonia and acetic acid, for example. In a case before referred to,[1] whilst the olfactory nerve was paralyzed and smell proper was wholly lost, the person was able to appreciate the contact of pungent substances; and the application of snuff to the Schneiderian membrane occasioned sneezing, because the ramifications of the nerve of the fifth pair or nerve of general sensibility were unaffected.

The immediate function of the sense of smell is to appreciate odours. In this it cannot be supplied by any other sense. The function is instinctive; requires no education; and is exerted as soon as the parts have attained the necessary degree of developement. In many respects the sense is intimately connected with that of taste; and the impressions made upon each are frequently confounded. In the nutritive function, the smell serves as a kind of advanced guard or sentinel to the taste; and warns us of the disagreeable or agreeble nature of the aliment; but if a substance repugnant to the smell be agreeable to the taste, the smell soon loses its aversion, or at least becomes less disagreeably impressed. The smell is not, however, in man so useful as a sentinel to the taste, as it is to animals: there are many bodies,—those containing prussic acid for example,—which are extremely pleasing by the odours they exhale, and yet are noxious to man. In the animal kingdom, this sense is greatly depended upon, and is rarely a fallacious guide. It enables animals to make the proper selection of the noxious from the innocent;—the alimentary from that which is devoid of nutriment;—the agreeable from the disagreeable; and the power appears to be instinctive or dependent upon inappreciable varieties of structure in the organs concerned in olfaction.

As an intellectual sense, smell is not entitled to a higher rank than taste. Its mediate functions are very limited. It enables the chemist, mineralogist, and perfumer, to discriminate bodies from each other. We can, likewise, by it form a slight—but only a slight—idea regarding the distance and direction of bodies, owing to the greater intensity of odours near an odorous body, than at a distance from it. Under ordinary circumstances, the information of this kind derived by olfaction is inconsiderable; but in the blind; and in the savage, who is accustomed to exercise all his external senses more than the civilized, its sphere of utility and accuracy is largely augmented. Of this we shall have to speak presently. We find it, too, surprisingly developed

[1] Page 710.

in certain animals; in which it is considered, by the eloquent Buffon, as an eye that sees objects not only where they are, but where they have been,—as an organ of gustation, by which the animal tastes not only what it can touch and seize, but even what is remote, and cannot be attained; and he esteems it a universal organ of sensation, by which animals are most readily and most frequently impressed; by which they act and determine, and recognise whatever is in accordance with, or in opposition to, their nature. The hound amongst quadrupeds affords us a familiar example of the extreme delicacy of this sense. For hours after the passage of game, it is capable of detecting its traces; and the bloodhound can be trained to indicate the human footsteps with unerring certainty.

Until of late years, it was almost universally believed, that many of the birds of prey possess an astonishingly acute sense of smell. Humboldt[1] relates, that in Peru, Quito, and in the province of Popayan, when they are desirous of taking the gigantic condor—*Vultur gryphus* of Linnæus—they kill a cow, or horse, and in a short time, the odour of the dead animal attracts those birds in numbers, and in places where they were scarcely known to exist. It is asserted, that vultures went from Asia to the field of battle at Pharsalia, a distance of several hundred miles, attracted thither by the smell of the killed![2] Pliny,[3] however, exceeds almost all his contemporaries in his assertions on this matter. He affirms, that the vulture and the raven have the sense of smell so delicate, that they can foretell the death of a man three days beforehand, and in order not to lose their prey they arrive upon the spot the night before his dissolution! The turkey-buzzard of the United States is a bird of this class, and it is surprising to see how soon they collect from immense distances after an animal has died in the forests. The observations and experiments of the ornithologist Audubon[4] would seem, however, to show that this bird possesses the sense of smell in a less degree than the carnivorous quadruped. He stuffed the skin of a deer with hay, and after the whole had become perfectly dry and hard, placed it in an open field on its back, and in the attitude of a dead animal. In the course of a few minutes a vulture was observed flying towards it, which alighted near, and began to attack it; tearing open the seams, and pulling out the hay; but finding that it could obtain nothing congenial to its taste, it took flight. It was found, too, that when animals in an advanced state of putridity were lightly covered over so as to prevent vultures from seeing them. they remained undisturbed and undiscovered, although the birds repeatedly flew over them. In some other experiments it was found, that birds of prey were attracted by well-executed representations of dead animals painted on canvass and exposed in the fields,—and in others, that young vultures, enclosed in a cage, exhibited no tokens of their perceiving food, when it could not be seen by them, however near them it was brought. These results—which were obtained, also, by Dr. Bachman in the presence of a number of scientific gentlemen of

[1] Rec. de Zoolog. et d'Anat. Comp., 2de livr., p. 73, Paris, 1807.
[2] Haller, edit. cit., tom. v. lib. xiv. p. 158.
[3] Hist. Nat., lib. x. cap. 6, p. 230, Lugd., 1587.
[4] Ornithological Biography, p. 33, Boston, 1835; Loudon's Mag. of Nat. Hist., vii. 167.

Charleston, South Carolina—are strange, inasmuch as the olfactory apparatus of the turkey-buzzard, when examined by the comparative anatomist, exhibits great developement, and admirable adaptation for acuteness of smell. They are confirmed, however, by more recent experiments on the condor by Mr. Charles Darwin,[1] a distinguished naturalist. He tied several condors by ropes in a long row at the bottom of a wall; and having folded up a piece of meat in white paper, he walked backwards and forwards carrying it in his hand at the distance of about three yards from them; but no notice whatever was taken of it. He then threw it on the ground within one yard of an old male bird, which looked at it for a moment with attention, but regarded it no more. With a stick he pushed it closer and closer, until at last the bird touched it with its beak; the paper was then instantly torn off with fury, and at the same moment every condor in the long row began struggling, and flapping its wings. "Under the same circumstances, it would have been quite impossible to have deceived a dog."

As the organ of smell, in all animals that respire air, is situate at the entrance of the organs of respiration, it is probable that its seat, in insects, is in the mouth of the air tubes. This sense appears to guide them to the proper kinds of food, and to the execution of most of the few offices they perform during their transient existence. Occasionally, however, they are deceived by the resemblance between odours of substances very different in other qualities. Certain plants, for example, emit a cadaverous odour similar to putrid flesh, by which the flesh-fly is attracted, and led to deposit its ova in places that can furnish no food to its future progeny.

As regards the extent of the organ of smell, man is undoubtedly worse situate than most animals; and all things being, in other respects, equal, it may be fair to presume, that those, in which the olfactory membrane is most extensive, possess the sense of smell most acutely. It is curious, however, that certain animals, which have the sense of smell in the highest degree, feed on the most fetid substances. The dog, for instance, riots in putridity; and the birds of prey, to which reference has been made, but whose acuteness of smell, we have seen, has been contested, have similar enjoyment. The turkey-buzzard is so fetid and loathsome, that his captors are glad to loosen him from bondage; and it is affirmed, that if his ordinary fœtor be insufficient to produce his release, he affords an irresistible incentive, by ejecting the putrid contents of his stomach upon them![2]

One inference may, perhaps, be drawn from this *penchant* of animals with exquisite olfactories for putrid substances;—that the taste of the epicure for game, kept until it has attained the requisite *fumet*, is not so *unnatural* as might at first sight appear.

Like the senses already described, that of smell is to a certain extent under the influence of volition:—in other words, it can be exerted *actively*, and *passively*. Its active exercise—as when we smell any substance to enjoy its sweets, or test its odorous qualities—generally

[1] Journal of Researches into the Natural History and Geography of the countries visited during the voyage of H. M. S. Beagle round the World, Amer. edit., New York, 1846.

[2] Wilson's American Ornithology, by Geo. Ord, Philad., 1803–1814.

requires prehension, the proper direction of the head towards the object, and more or less contraction of certain muscles of the alæ nasi. Doubtless, here again, the papillæ are capable of being erected under attention, as in the senses of taste and touch. On the other hand, we can throw obstacles in the way of the reception of disagreeable odours; and, if necessary, prevent their ingress altogether, by compressing the nostrils with the upper extremity.

Lastly:—like the other senses, smell is capable of great improvement by education. The perfumer arrives, by habit, at an accurate discrimination of the nicest shades of odours; and the chemist and the apothecary employ it to aid them in distinguishing bodies from each other; and in pointing out the changes that take place in them, under the influence of heat, light, moisture, &c. In this way, it becomes a useful chemical test. The effect of education is likewise shown, by the difference between a dog kept regularly accustomed to the chase, and one that has not been trained. For the same reason, in man, the sense is more exquisite in the savage than in the civilized state. In the latter, he can have recourse to a variety of means for discriminating the properties of bodies; and hence has less occasion for acuteness of smell than in the former; whilst, again, in the latter state, numbers destroy the sense to procure pleasure. The use of snuff is one of the most common of these destructive influences.

Of the acuteness of the sense of smell in the savage we have an example on the authority of Humboldt: he affirms, that the Peruvian Indian in the middle of the night can distinguish the different races by their smell,—whether they are European, American Indian, or negro. To the same cause must be ascribed the delicacy of olfaction generally observed in the blind. The boy Mitchell,[1] who was born blind and deaf, and whose case will have to be referred to hereafter, was able to distinguish the entrance of a stranger into the room by smell alone. A gentleman, blind from birth, from some unaccountable impression of dread or antipathy, could never endure the presence of a cat in the apartment. One day, in company, he suddenly leaped up; got upon an elevated seat; and exclaimed, that a cat was in the room, begging them to remove it. It was in vain that the company, after careful inspection, assured him he was under an illusion. He persisted in his assertion and state of agitation; when, on opening the door of a small closet, it was found that a cat had been accidentally shut up in it.

[1] Wardrop's History of James Mitchell, Lond., 1813; and Dugald Stewart's Elements of the Philosophy of the Human Mind, iii. 401, 3d edit., Lond., 1808.

END OF VOL. I.